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**LOW VOLATILE ORGANIC COMPOUND  
(VOC) CHEMICAL AGENT RESISTANT  
COATING (CARC) REMOVAL AND  
DISPOSAL**

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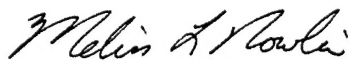
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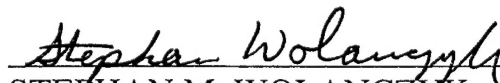
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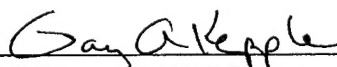
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## EXECUTIVE SUMMARY

<b>Title:</b>	LOW VOC CARC REMOVAL and DISPOSAL
<b>AF Customer:</b>	Air Force Research Laboratory, Coatings Technology Integration Office
<b>Report Period:</b>	October 1998 – November 2000

### 1.0 Introduction

The Strategic Environmental Research and Development Program (SERDP) funded a tri-service effort to develop a low Volatile Organic Compound (VOC) Chemical Agent Resistant Coating (CARC) system for use on Army, Marine Corps, and Air Force systems. The overall objective of this project was to develop a Low VOC CARC system suitable for use on military equipment by all services, in which the materials and processes for the reformulation, application, stripping and disposal are optimized and in compliance with the current and anticipated regulatory requirements.

The SERDP technical effort was divided into three phases consisting of formulation, application, and removal with each agency overseeing one of the phases. The Army Research Laboratory (ARL) conducted the formulation efforts; Naval Surface Warfare Center, Carderock Division (NSWCCD) the application studies; and AFRL the removal studies.

### 2.0 Approach

Production depaint requirements were established in terms of stripping efficiencies in relation to production throughput, and surface finish constraints imposed for acceptable substrate conditions following CARC system removal. Baseline testing of the existing CARC system was accomplished to provide a basis for comparative strippability analysis. The stripping studies utilized a full range of substrates, including metallic and nonmetallic (composites) materials in the test protocols.

Stripping processes either identified by a requirements survey, or other processes that were expected to be introduced into DoD maintenance operations in the near future comprised the stripping processes evaluated. Strip rates derived from baseline testing were compared with strip rates derived from testing with the SERDP Low VOC CARC to assess potential impact on maintenance operations.

### 3.0 Results

The results of the CARC stripping requirements survey indicated that the preponderance of this work is done with some form of dry abrasive blasting, and other stripping is generally done by chemical methods. This survey also indicated that there is a common

concern pertaining to any increases of hazardous waste products associated with the SERDP Low VOC CARC.

CARC strippability data for the various dry media depaint processes suggests that the strippability of the SERDP Low VOC CARC should not be expected to present an adverse impact to depaint operations.

The chemical strippability data suggests that stripping productivity of the SERDP Low VOC CARC using these processes is not expected to be impacted significantly.

Strippability with the SERDP Low VOC CARC with applied light energy processes (emerging technologies either being implemented or of great interest for implementation) must be considered a non-issue. No data were developed that indicate that the SERDP Low VOC CARC will present any strippability problems with these processes, and very likely with any similar processes.

#### **4.0 Conclusions**

Based on the results of this study there is no firm foundation supported by the data to suggest any need for modifying or replacing current depaint processes to accommodate the SERDP Low VOC CARC. Since there are no anticipated changes required for current stripping processes, i.e., no increase of the waste stream for these processes, there will also be no need to be concerned over waste disposal. The SERDP Low VOC CARC should be considered a likely "drop-in" technology from the regards of strippability.

## ABBREVIATIONS and ACRONYMS

ANAD	Anniston Army Depot
ARL	The Army Research
ASTM	American Society for Testing and Materials
CARC	Chemical Agent Resistant Coating
CCAD	Corpus Christi Army Depot
CWA	Craig Walters Associates
DFTM	Dry Film Thickness Measurements
DMB	Dry Media Blast
GLC	General Lasertronics Corporation
HAPs	Hazardous Air Pollutants
IAW	In Accordance With
LEAD	Letterkenny Army Depot
MCLB	Marine Corps Logistics Base, Albany, GA
ND. YAG	Neodymium-doped, Yttrium Aluminum Garnet
NSWCCD	Naval Surface Warfare Center, Carderock Division
PMB	Plastic Media Blast
PMBU	Plastic Media Blast Unit
RRAD	Red River Army Depot
SERDP	Strategic Environmental Research Development Program
SM-ALC	Sacramento Air Logistics Center
TYAD	Tobyhanna Army Depot
UV/CON	Ultra-violet/Condensate
VOC	Volatile Organic Compound
WBCC	Water Borne Camouflage Coating
YAG	Yttrium Aluminum Garnet

## **LOW VOC CARC REMOVAL and DISPOSAL**

### **1.0 INTRODUCTION**

The Strategic Environmental Research and Development Program (SERDP) funded a tri-service effort to develop a low Volatile Organic Compound (VOC) Chemical Agent Resistant Coating (CARC) system for use on Army, Marine Corps, and Air Force systems. The overall objective of this project was to develop a SERDP Low VOC CARC system suitable for use on military equipment by all services, in which the materials and processes for the reformulation, application, stripping and disposal are optimized and in compliance with the current and anticipated regulatory requirements. The primary objective is to reduce the VOC of the polyurethane topcoat from 3.5lb/gal to 1.8lb/gal. A secondary objective will be to eliminate the hazardous air pollutants (HAPs) and toxic solvents used in the current topcoat formulation. The secondary objective was to develop a "drop in" low VOC replacement for the current CARC material. New application and removal processes and equipment were to be minimized as much as possible.

The technical effort has been divided into three phases consisting of formulation, application, and removal with each agency overseeing one of the phases. The Army Research Laboratory (ARL) conducted the formulation efforts; Naval Surface Warfare Center, Carderock Division (NSWCCD) the application studies; and AFRL the removal studies.

In support of the project, the Air Force Research Laboratory (AFRL), in conjunction with Southwest Research Institute (SwRI), initiated in-house coatings stripping, and stripping process waste disposal studies task to determine how existing processes should be modified (if necessary) to meet the depaint requirements of each service. This action was pursued in order that a complete CARC system, i.e., coating formulation, application, and stripping, will be made available through the efforts of this SERDP project.

ARL has developed a low VOC formulation based on water-reducible chemistry along with polymeric bead extenders that met the VOC goals and exhibited improved mechanical and weathering properties than the current MIL-C-46168 CARC. This material was manufactured by Hentzen Coatings as part of a pilot plant, quality performance batch.

Production depaint requirements were established in terms of stripping efficiencies in relation to production throughput, and surface finish constraints imposed for acceptable substrate conditions following CARC system removal. Baseline testing of the existing CARC system was accomplished to provide a basis for comparative strippability analysis. Both the application and stripping studies utilized a full range of substrates, including metallic and nonmetallic (composites) materials in the test protocols.

## 2.0 EXPERIMENTAL

Efforts have been completed to characterize typical depaint processes and requirements for removal of the current CARC, or alternative systems<sup>1</sup>. Baseline information pertaining to depaint processes was acquired through on-site and written surveys of Army, Marine Corps, and Air Force depot operations. A detailed strippability test plan was compiled on the basis of this characterization which reflected those depaint processes identified through the survey efforts. Strippability testing was also accomplished in a manner intended to replicate the range of typical stripping processes used for maintenance operations involving use of CARC, or equivalent coatings systems.

### 2.1 Depaint Process Characterizations

Various DoD maintenance operations were visited to obtain on-site information pertaining to the depaint processes used for the current CARC, or alternative systems (the Marine Corps does not use the same coating as the Army) associated with those operations. The selection of the operations to visit was intended to provide representative CARC depaint information for the different DoD services participating in this project. Baseline information pertaining to associated depaint requirements, and range of applications associated with these operations was acquired through these efforts. Supplementary information was also obtained from these sites by use of written questionnaires. The specific sites visited and polled included the following:

Anniston Army Depot (ANAD)  
Letterkenny Army Depot (LEAD)  
Tobyhanna Army Depot (TYAD)  
Red River Army Depot (RRAD)  
Corpus Christi Army Depot (CCAD)  
Marine Corps Logistics Base (MCLB), Maintenance Center Albany, Albany, GA  
Marine Corps Logistics Base (MCLB), Maintenance Center Barstow, Barstow, CA  
Sacramento Air Logistics Center (SM-ALC).

The on-site survey efforts were concluded in January 1998, and efforts to obtain supplementary information via a questionnaire sent to these sites were concluded in the year 1999. Final results derived through this survey are given in Appendix A.

### 2.2 Strippability Test Plan

Information derived through the Depaint Process Characterizations phase of this study provided the basis for development of a CARC Strippability Test Plan. The test plan

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<sup>1</sup> The Water Borne Camouflage Coating (WBCC) is used by the Marine Corps Logistics Directorate (MIL-C-29475) instead of MIL-C-46168D. This coating meets local environmental regulations, but is not an approved CARC.

included considerations for testing of the coatings systems currently used as CARC, the SERDP Low VOC CARC formulation, typical primers associated with different combinations of substrate materials, varying degrees of substrate sensitivity to damage produced by a stripping process, and possible variations of strippability due to aging conditions. The test plan also includes on-site testing of typical abrasive blast depaint processes, testing of a commercially available ablative process, and laboratory tests of chemical stripping processes typically used for stripping of small parts.

The test plan was designed to derive sufficient data to determine any necessity for modification, or replacement of any of the current stripping processes identified by this study. This was to be accomplished through evaluations of only significant representative materials and stripping processes, not every possible variable combination. The inability of various sites surveyed to define a quantifiable production requirement prompted the concept of concurrent testing of the new SERDP Low VOC CARC along with current CARC systems at different sites or operations, using the actual stripping processes of those operations to provide baseline data for comparison.

The selection of substrate and other test materials (Appendix B) was made through common consent of the DoD representatives comprising the work group for this SERDP funded project. The specific site, and/or stripping process evaluations were selected to avoid redundant testing. This approach assumes that a stripping process used at more than one operation will not exhibit fundamental changes from site-to-site even when tested at a single site. This was considered reasonable since this effort is designed to identify fairly gross strippability changes, or production impacts, and slight variations between different operations would not be considered significant. In addition, by group consensus, depaint processes that are seldom used, or comprise a very low use rate in relation to overall workload were not included into considerations for assessment.

Original planning also included considerations for any materials testing to qualify any new or modified depaint processes. This was considered prudent since it was very possible that a coating that was tougher to remove, might require a more aggressive depaint process. In turn, if a more aggressive process were to be used to maintain production requirements, this process would have to be demonstrated to be safe to use, dependent on the substrate. This concern holds especially true with more damage sensitive materials, such as the thinner aluminum alloys and composite materials, common to aerospace construction.

Other data acquired in accordance with the test plan as an effort to ensure quality control, and coating systems integrity included dry film thickness measurements during test material preparations. Additional data, which was outside of the Formal Test Plan, were developed for two pulsed Nd:YAG laser stripping systems since these processes represent emerging depaint technology that was considered to be of general interest. As such, these assessments were considered informative only, and had no significant bearing on overall project results.



## 2.3 CARC Strippability Test Materials and Preparations

Strippability assessment substrate materials included:

2024-T3 bare alloy, 0.063 inch and 0.032 inch (used with assessments of less aggressive depaint processes)  
1010 alloy steel, 0.063 inch  
fiberglass/epoxy, 8 ply (0/90 weave), 0.062 inch, per MIL-I-24768/27 GEE-F

Material preparations included:

Aluminum surface preparations and chromate conversion treatment in accordance with (IAW) Air Force T.O. 1-1-8,  
Steel surface preparations with Zinc-Phosphate pre-treatment IAW T-T-C 490  
Fiberglass test panels were prepared IAW T.O. 1-1-24  
Primers and Topcoats were applied IAW the applicable MIL-SPECS.

Coatings used for strippability assessments included:

Primer, MIL-P-53022 (used on steel and aluminum substrate)  
Primer, MIL-P-23377, Type 1, Class C (used on aluminum substrate only)  
Topcoat, MIL-C-46168D CARC 383 Green, Color # 34094 (baseline/current CARC)  
Topcoat MIL-C-29475 Water Borne Camouflage Coating (WBCC) Color383 Green, Color # 34094, (baseline Marine Corps topcoat)  
Topcoat, SERDP Low VOC CARC - Light Grey, Color # 36251  
Topcoat, SERDP Low VOC CARC – 383 Green, Color # 34094

Materials conditioning was applied to either simulate natural aging, or accelerated coatings curing. Natural aging was simulated by cyclic exposure to UV light, followed by a water condensate period (UV/CON). This cycle was 8 hours of UV + 4 hours of condensate, and was repeated for a total of 40 complete cycles. The UV/CON conditions were as follows:

UV exposure @ 70 °C  
Condensate exposure @ 50 °C  
UV exposure will be with UVB 313 bulbs at an irradiance of 0.63 W/m<sup>2</sup>, or UVA 340 bulbs<sup>2</sup> at an irradiance of 0.72 W/m<sup>2</sup>.

Accelerated coatings curing/aging by oven has been used by the Air Force for several years for conditioning strippability test materials, and it is also similar to practices sometimes followed in maintenance operations to accelerate production throughput for

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<sup>2</sup> UVA bulb exposure was added to the test matrix as another method of simulated aging at the request of the Army Research Laboratory (ARL). ARL expressed some concern that the UVB bulb exposure could be too harsh, thereby possibly skewing the strippability data.

painted materials. The oven aging used for this project consisted of exposure at for 96 hours at 210 °F.

**Note:** All test materials were given a minimum of 7 days cure at room temperature (75±5 °F) prior to any other conditioning.

## 2.4 CARC Strippability Assessments of Standard Blast Processes

The dry media blast (DMB) strippability assessments were conducted with various depaint processes at the following sites:

<u>Maintenance Site</u>	<u>Depaint Process</u>
Anniston AD	Stainless Steel Blast
Letterkenny AD	Walnut Hull Media Blast
Tobyhanna AD	Zirconia Alumina Abrasive Blast
Corpus Christi AD	Wheat Starch Media Blast
MCLB Albany	Garnet Media Blast and Type II Plastic Media Blast (PMB)
Ogden ALC <sup>3</sup>	Type V PMB.

All blast depaint processes were assessed in typical production modes, i.e., blast processes were applied manually and with process parameters typical for that specific depaint operation. Nozzle standoff distances and blast impingement angles are approximate, and varied somewhat through operator response to stripping effectiveness at the time of the assessment.

Test panels were stripped in an order based semi-random selection of test panels. Strip rates were calculated through measuring the area stripped completely, for the elapsed time for the stripping. Irregular stripped areas had 4-6 measurements made in a given direction, and the average of these dimensions were used to calculate area. Elapsed time was measured with a stopwatch and recorded to the nearest 0.1 second.

### 2.4.1 Strippability Process Parameters

The process parameters for each of blast processes, and the chronological order that strippability assessments were conducted are as follows:

Walnut Hull - Blast Pressure = 70 psi  
Standoff Distance of 8 - 12 inches  
Blast Impingement Angle of 60° - 80°

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<sup>3</sup> A portion of the workload identified at SM-ALC was transitioned to Ogden ALC (OO-ALC) during the course of this study, which necessitated conducting assessments with the depaint process used by OO-ALC. OO-ALC also represented an opportunity to conduct assessments with a Type V PMB depaint process.

Media Size = 20 Mesh  
Nozzle - 1/2 inch Diameter Standard Venturi

Zirconia Alumina - Blast Pressure = 90 psi  
Standoff Distance of 4 - 6 inches  
Blast Impingement Angle of approximately 90°  
Media Size = Fine  
Nozzle - 3/16 inch Diameter Standard Venturi

Type II PMB - Blast Pressure = 90 psi  
Standoff Distance of 18 - 20 inches  
Blast Impingement Angle of 60° - 80°  
Media Size = 16 - 20 mesh  
Nozzle - 1/2 inch Diameter Standard Venturi

Garnet Abrasive - Blast Pressure = 80 psi  
Standoff Distance of 36 - 40 inches  
Blast Impingement Angle of 60° - 80°  
Media Size = 30 - 60 mesh  
Nozzle - 1/2 inch Diameter Standard Venturi

Stainless Steel Shot - Blast Pressure = 80 psi  
Standoff Distance of 8 - 12 inches  
Blast Impingement Angle of 60° - 80°  
Grit Size = 50  
Nozzle - 1/2 inch Diameter Standard Venturi

Type V PMB - Blast Pressure = 40 psi  
Standoff Distance of 18 - 20 inches  
Blast Impingement Angle of 60° - 80°  
Media Size = 20 - 30<sup>4</sup> mesh  
Nozzle - 1/2 inch Diameter Standard Venturi

Wheat Starch - Blast Pressure = 35 psi  
Standoff Distance of 12 - 18 inches  
Blast Impingement Angle of approximately 60°  
Media Size = 20 - 30 mesh<sup>5</sup>  
Nozzle - 1/2 inch Diameter Standard Venturi.

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<sup>4</sup> OO-ALC uses the 20 - 30 mesh media for replenishment, and sizing screens are used to maintain a 20 - 50 mesh distribution of the working media.

<sup>5</sup> A majority of media size is maintained at a range of 30 - 90 mesh through special sizing screens in-line with the media reclamation system incorporated into the blast facility. The 20 - 30 mesh distribution represents the virgin, or make-up media, mesh distribution.

## 2.5 CARC Strippability with Chemical Depaint Processes

Although the original intent and scope of this SERDP project was focused on evaluating stripping processes other than chemical stripping, it was determined at the end of the Depaint Process Characterization phase that there is a significant level of CARC stripping by chemical agents. This type of stripping process is used primarily for smaller parts, and/or parts that have been removed from a larger part (vehicle, aircraft, etc.) during the maintenance process.

To this end laboratory testing of representative chemical stripping processes were added to the CARC Strippability Test Plan. The processes and associated substrate materials for evaluation were based on current methods used by the various maintenance operations surveyed. A small scale laboratory replication of production chemical stripping processes was considered a simpler, more reliable approach to this testing, and was included in the test plan in this fashion. Parameters for the chemical stripping processes were supplied by maintenance operations involved in the initial survey efforts.

Process parameters were replicated in a laboratory environment, and qualitative assessments of each chemical stripping process was conducted. The procedures used for these tests are presented below. The chemical stripping processes, and the maintenance operations using these processes identified by this study, are given in Table D-1, Appendix D.

### 2.5.1 Chemical Depaint Process Testing Procedures

In general the chemical strippability testing procedures consisted of the immersion of test specimens, prepared as noted in Appendix D, into a bath of a chemical stripper. The temperature of the immersion bath was controlled during the dwell period, except as noted, by placing the beaker containing the chemical stripper in an explosion proof, temperature controlled oven. Temperatures for these tests were maintained per parameters supplied by the individual maintenance operations. The ambient temperature testing was conducted in an area for which the measured temperature was 26 °C (78 °F). The test area on the individual test panels was  $\approx 15 \text{ cm}^2$  (6 in<sup>2</sup>). Panel edges were masked with pressure sensitive aluminum backed tape to prevent chemical intrusion in an effort to mitigate any edge effects which would tend to artificially enhance strippability.

## 2.6 CARC Strippability Assessments of Applied Light Energy Processes

CARC strippability assessments were conducted with several applied light energy paint stripping processes. One of the three processes, the Boeing FlashJet™ system, is a newer technology that will be used at several DoD maintenance operations in the very near future. FlashJet™ uses high power xenon (UV light) pulses to ablate the coating system. The FlashJet™ process is applied concurrently with a “scrubbing” of the coating residue

by a CO<sub>2</sub> pellet blasting system. The CO<sub>2</sub> blast also provides cooling of the substrate. The primary use project for this process is on composite materials. For that reason the evaluations made with the FlashJet™ process were conducted with fiberglass test materials only.

The FlashJet™ process parameters that were observed during assessments with this process are as follows:

Flash Head Traverse Rate - 0.9 in/sec

Input - 2300 volts

Flash Rate - 3.6 Hz

Standoff - 2.2 inches measured from lens assembly.

The other two processes are based on pulsed Nd:YAG laser, which emits radiation in the infrared light range. The processes differ in the method by which coatings removal is accomplished. The laser system produced by General Lasertronics Corporation (GLC) is designed to ablate the coating system. The other laser system, which is produced by Craig Walters Associates (CWA) relies on laser shock. These different effects are achieved through different combinations of power, pulse duration, and pulse frequency.

The General Lasertronics Corporation (GLC) Laser Coating Remover as used for this project is a controlled tool for removal of coatings and finishes from the external surfaces of aircraft. The semi-automated system selectively removes coating/finish layers using energy pulses from a Q-switched, solid state, laser. The laser is a Neodymium-doped, Yttrium Aluminum Garnet (Nd: YAG), so the wavelength of the pulse light energy is appropriate for transmission along an optical fiber. The laser light pulses were transmitted to a lightweight, hand-held end effector through flexible optical fiber. The laser pulse width was approximately 130 ns and the laser wavelength was 1064 nm. The fluence used in the tests was 3.1 J/cm<sup>2</sup> per pulse and the average laser power employed was 100 W.

The CARC test panels stripped by the CWA system used a recently developed handheld tool, which delivers pulsed Nd:YAG laser beams from a 40-foot umbilical cable to a work surface. Three separate laser beams impinged the work piece simultaneously, each over a 4-mm diameter circle. The three circular irradiance areas are automatically scanned transversely to the stripping path, which is formed as the operator draws the tool along the work piece surface. The stripped areas on the CARC panels were formed by several passes on a single area. The fluence used in the tests was 1.5 J/cm<sup>2</sup> per pulse. The pulse repetition rate was 12 Hz and the average laser power employed was 6.9 W. The laser pulse width was <20 ns and the laser wavelength was 1064 nm.

## **3.0 RESULTS**

### **3.1 Depaint Process Characterization Results**

Maintenance operations representing each branch of the DoD involved in this effort were visited, from September 1997 through January 1998. Much of the information necessary to develop comprehensive documentation of CARC, or an equivalent coating system, stripping was obtained. These visits established the basis for on-going relations with each of the participants, and each of these facilities has given verbal approval for return visits. Future visits were anticipated to accomplish the milestones of this project, such as field testing and process integration. A synopsis of the findings relative to each site visited are given below. Appendix A contains charts summarizing all of the findings obtained in this effort.

#### **3.1.1 Anniston Army Depot**

Anniston was visited September 1997. This visit obtained on-site information, and identified Mr. Steve Guthrie as the point of contact for CARC issues. The current CARC stripping requirements associated with this depot involve CARC removal for overhaul, repair, and inspection of vehicle and artillery components.

Anniston has previously conducted technical studies to support selection of more durable dry media for use in CARC depainting efforts. This study specifically compared the results of mineral based dry media to that of steel shot. The survey of current CARC removal needs versus future needs for Anniston identified the continued concern of disposal of associated hazardous waste products. Anticipated increases of workload produced by base realignments make this concern more significant, since the volume of the waste stream would be expected to increase proportionally.

The request to identify current and future production requirements was cited as not being readily quantifiable. Current and future environmental concerns for the Anniston Army Depot continue to concentrate on hazardous waste disposal of dry media. Other information from Anniston is presented in Appendix B.

#### **3.1.2 Marine Corps Logistics Base, Albany, GA**

A visit to the Marine Corps Logistics Base, Albany, GA was conducted in October 1997. This visit obtained on-site information, and identified Mr. Ron Vargo as the point of contact for CARC (MIL-C-29475) stripping issues. The current CARC stripping requirements for this maintenance center involve the removal of coatings systems for overhaul, repair, and inspection of heavy equipment components.

The survey of Albany's current CARC removal needs versus future needs identified the need for a chemical stripper to remove CARC from parts that can not be abrasively

blasted. To this end, Albany has previously conducted studies to assess replacing methylene chloride stripping processes with environmentally compliant chemical strippers. High pressure water blasting as an alternative to dry media blasting has been evaluated by Albany with favorable results, but no implementation of such a process has been initiated. Current and future environmental concerns were identified as a continuing need for the recycling of depaint process waste products, waste stream reduction, cost reductions associated with disposal issues, and a prerequisite that acceptable stripping processes must minimize the potential for release of hazardous waste products.

### **3.1.3 Tobyhanna Army Depot**

The visit to Tobyhanna Army Depot was conducted in November 1997. This visit obtained on-site information, and identified Mr. Ron Scarnulis as the point of contact for CARC issues. The current CARC stripping requirements involve the removal of CARC from various electronic components/equipment for overhaul, repair, and inspection. These components contain substrate materials ranging from fiberglass to heavy steel structures. The primary stripping methods identified for CARC removal are dry media stripping and chemical baths.

Tobyhanna identified no previous technical efforts directed towards evaluation of CARC depaint processes. The Tobyhanna survey of current CARC removal needs versus future needs identified a requirement that integration of the SERDP Low VOC CARC will provide effective, economical CARC removal methods for thin skinned substrates while generating minimal hazardous waste products. Current and future production requirements were cited as not being readily quantifiable.

### **3.1.4 Letterkenny Army Depot**

The visit to Letterkenny Army Depot was conducted in November 1997. This visit obtained on-site information, and identified Mr. Dennis Reed as the point of contact for CARC issues. The current CARC stripping requirements associated with this depot involve the removal of CARC for overhaul, repair, and inspection of heavy equipment and missile components. It was determined that the primary method of CARC stripping is dry media blasting, and these processes are augmented by chemical stripping on a smaller scale.

### **3.1.5 Marine Corps Logistics Base, Barstow, CA**

A visit to Marine Corps Logistics Base, Barstow, CA was made in November 1997. This visit obtained on-site information, and identified Mr. Leonard Jimenez as the point of contact for coatings stripping issues<sup>6</sup>.

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<sup>6</sup> MIL-C-29475 is used to comply with local environmental regulations for the Navy/Marine Corps depots chemical agent resistance requirements.

The current stripping requirements are for coatings removal for overhaul, repair, and inspection of heavy equipment components. Other stripping work for various operations is done by request, which may add some unforeseeable variances to the workload, current acceptance criteria, and the stripping processes used since this may be governed by customer requirements.

Barstow has previously conducted technical studies involving process containment, which concentrated on the reduction of air emissions. Barstow also indicated that the area the depot is located within has a very low tolerance to any possible source of pollution to the water supply. This was given as the reason no significant considerations have been given to water blast technology for CARC, and would restrict such technology for considerations as an alternative stripping process for this operation. There are no changes anticipated of current coatings removal workload versus future coatings removal workload through any addition or reduction of work due to base realignments.

The request to identify current and future production requirements was cited as not being readily quantifiable. Current and future environmental concerns for this maintenance operation continue to concentrate on maintaining compliance with stringent California State EPA requirements.

### **3.1.6 Sacramento Air Logistics Center (SM-ALC)**

SM-ALC was visited in December 1997, and the point of contact at that time was Mr. Ed White. Due to changes in staff associated with base realignments and restructuring within the ALC, Mr. White is no longer available for this effort, and no alternative has been identified. It is also anticipated that most of the maintenance work done at SM-ALC that might involve a CARC requirement is to be transitioned to other maintenance operations that perform similar maintenance functions. Efforts are being made to ascertain the status of the transition of this workload.

The only applications identified by SM-ALC that have any possible CARC requirements are associated with maintenance activities for vans and shelter components used with ground radar. SM-ALC identified no previous technical efforts specifically for the development for CARC depaint processes. Tobyhanna Army Depot, which has been identified as the operation likely to receive the bulk of the transitioned workload, has indicated that it will use the depaint process specified by the AF System Directorate responsible for these products. The primary stripping process used by SM-ALC for this application is dry abrasive blasting with Type II plastic media, and it is assumed that this will continue to be the depaint process used by any operations assuming responsibility for these applications.

### **3.1.7 Red River Army Depot**

The visit to Red River Army Depot was conducted in December 1997. This visit obtained on-site information, and identified Mr. Mike Starkes as the point of contact for



CARC issues. The primary CARC stripping requirements for this depot involve the removal of CARC for overhaul, repair, and inspection of the Bradley Fighting vehicle and associated components.

The survey of Red River's current CARC removal needs versus potential for future needs identified the continued concern for disposal of hazardous wastes. Like other maintenance operations participating in this survey effort, Red River would be very reluctant to accept any modifications of depaint processes that could produce any increase of hazardous waste products.

The request to identify current and future production requirements identified a slight reduction, from 95 to 75 man-hours/shift, in aluminum substrate workload while steel substrate workload is projected to remain a constant 5 shift/shift. Strippability testing results of baseline (current CARC, or equivalent) versus the SERDP Low VOC CARC will be used to determine any impacts on these requirements.

Other environmental concerns expressed by Red River Army Depot for now and the immediate future regard EPA mandated reductions in hexavalent chromium exposure, which will impact cleaning processes used at the Depot.

### **3.1.8 Corpus Christi Army Depot**

A visit to Corpus Christi Army Depot was conducted in January 1998. This visit obtained on-site information, and identified Mr. Ed Cooper as the point of contact for CARC issues. The CARC stripping requirements associated with Corpus Christi involve the removal for overhaul, repair, and inspection of helicopter airframes and components.

Corpus Christi has conducted technical studies to reduce the utilization of hazardous chemicals for coatings stripping, which include CARC systems. These studies included reviews of wheat starch blasting, plastic media blasting, laser removal, flash lamp, carbon dioxide blasting, ice crystal blasting, and water blasting. To date, Corpus Christi has successfully implemented a wheat starch media blasting facility to use with more damage sensitive components/substrate materials. Other dry media blasting, such as Type V plastic media is also used for applications that are not as sensitive.

The Corpus Christi survey of current CARC removal needs and future needs identified a requirement to improve design deficiencies of their existing media facilities to match throughput requirements. These facilities have been given funding for a refurbishment project, and are currently being repaired/upgraded. This may dictate changes in the strippability testing associated with this maintenance operation, but this has not been determined at this time.

The request to identify current and future production requirements were provided as; FY98 estimates ~4358 hours based on 40 hour week for 3 men and 69 aircraft, FY99 and

future not known. On-site testing will be conducted to compare current process(es) stripping efficiencies for current CARC and SERDP Low VOC CARC.

Current and future environmental concerns for the Corpus Christi Army Depot continue to concentrate on the elimination of the use of methylene chloride for stripping, disposal of wheat starch, and other spent dry blast media containing chromated materials from the primer component of the CARC system. Evaluations of an ablative depaint process utilizing high energy flashes of UV light have been initiated as a possible means to achieve these goals.

### **3.2 CARC Strippability with Standard Blast Processes**

Assessments were conducted to establish strippability comparisons of the SERDP Low VOC CARC to current coating systems. The baseline coatings were considered to be either the current CARC, MIL-C-46168, or the Marine Corps equivalent, MIL-C-29475 used with either MIL-P-53022 or MIL-P-23377 primers. Strippability data were developed with different combinations of topcoat, substrate, primer, aging conditions, and to a limited extent topcoat color per the Project Test Plan (Appendix B). All DMB strippability data, with associated graphical presentations, acquired in this effort are given in Appendix C. The graphical presentations represent a mean strip rate value, i.e., area of coating system removed per unit time ( $\text{ft}^2/\text{min}$ ), for specific combinations of primer, topcoat, and substrate. The strip rate data for different aging conditions were included in the mean value for a given combination. Individual data points may be seen in the tabulated data.

#### **3.2.1 Walnut Hull Abrasive Blasting**

The strippability data in tabulated and graphical formats for this process are found in Table C-1, and Figures C-1 through C-3, Appendix C.

A comparison of the stippability data (Table C-1) for oven cured test materials versus UV/CON conditioned test materials indicates that the oven cured coating systems were generally tougher to remove than UV/CON materials with this DMB process. This is based on the observation that the strip rate data for the oven cured materials is lower for 6 of the 9 data sets (specific combinations of substrate+primer+topcoat). At the same time it appears that there is little difference between the strippability data for either of the UV/CON.

As may be seen in the data plotted in Figure C-1, the SERDP Low VOC CARC is stripped more easily than both the current CARC (MIL-C-46168), and the WBCC (MIL-C-29475), with MIL-P-23377 primer on aluminum substrate. From Figure C-2 it may be observed that, while the differences are relatively small, SERDP Low VOC CARC strippability is not as good on steel substrate with the combination of MIL-53022 primer and the two baseline topcoats.

Figure C-3 shows that stripping of the topcoat only, of the SERDP Low VOC CARC is better than the old CARC, but the difference is not real large. However, the strippability of the WBCC over MIL-P-53022 on the aluminum substrate is much greater than that of the SERDP Low VOC CARC.

It should be noted that in all instances of this data set (WBCC/MIL-P-53022), the mean strip rates used for comparison are for the topcoat only. Letterkenny production engineering support indicated that this condition would be satisfactory, and typically a depaint technician would stop stripping efforts at that point.

### **3.2.2 Zirconia Alumina Abrasive Blasting**

The strippability data in tabulated and graphical formats for this process are found in Table C-2, and Figures C-4 through C-6, Appendix C.

A comparison of the strippability data (Table C-2) for oven cured test materials versus UV/CON conditioned test materials indicates that the oven cured coating systems were generally tougher to remove than UV/CON materials with this DMB process. This is based on the observation that the strip rate data for the oven cured materials is lower for the majority of the 9 data sets (specific combinations of substrate+primer+topcoat). Some of the differences observed for this comparison are not that substantial, and do not tend to make a particularly strong argument that the oven aged materials are significantly tougher. The strippability data also does not appear to support any argument that there are significant differences between the strippability for either type of UV/CON conditioning.

Figures C-4 and C-6, Appendix C, again indicate that the SERDP Low VOC CARC is generally easier to strip than the baseline coatings. An exception may be seen in Figure C-5, in that the SERDP Low VOC CARC appears tougher to remove than either baseline coating with MIL-P-53022 on aluminum substrate. The difference illustrated in this figure between the SERDP Low VOC CARC and the WBCC is greater than the difference observed between new and current CARC.

### **3.2.3 Type II PMB**

The strippability data in tabulated and graphical formats for this process are found in Table C-3, and Figures C-7 and C-8, Appendix C. As may be seen in Figures C-7 and C-8, some strippability comparisons were made between SERDP Low VOC CARC colors (Grey and Green). All data for this process were developed with aluminum substrate materials since this process is typically not considered aggressive enough to use on steel substrate.

A comparison of the strippability data (Table C-3) for oven cured test materials versus UV/CON conditioned test materials indicates that the oven cured coating systems were generally tougher to remove than UV/CON materials with this DMB process. This is

based on the observation that the strip rate data for the oven cured materials was determined to be lower for 6 of the 9 data sets (specific combinations of substrate+primer+topcoat). Some of the differences observed for this comparison are somewhat greater than seen previously, and do make a bit stronger argument for tougher strippability of the oven aged materials. These strippability data do not appear to support any argument that there are significant differences between the strippability for either type of UV/CON conditioning.

Strippability data for this DMB process indicate that the SERDP Low VOC CARC based on the mean of the strippability data for the two colors is removed more easily than either baseline system with MIL-P-23377 primer. As may be seen in Figure C-7, both colors are stripped more readily than either baseline system.

Figure C-8 indicates that data for the MIL-P-53022 primer exhibits some variances in strippability. The grey strips easier than the WBCC, but the strippability of the AF gray is nearly identical to the current CARC. In this particular data set the Navy green appears to be the toughest of the set, as opposed to the data presented in Figure C-7 showing a better strip rate for the green. The mean strip rate for the two SERDP Low VOC CARC colors is slightly higher than the WBCC, but lower than the current CARC.

### **3.2.4 Garnet Abrasive Blasting**

The strippability data in tabulated and graphical formats for this process are found in Table C-4, and Figures C-9 through C-11, Appendix C.

A comparison of the strippability data (Table C-4) for oven cured test materials versus UV/CON conditioned test materials does not support any argument that the oven cured coating systems were tougher to remove than UV/CON materials with this DMB process. These strippability data do not appear to support any argument that there are significant differences between the strippability for either type of UV/CON conditioning.

As may be seen in Figure C-9, the strip rate for the SERDP Low VOC CARC is lower, i.e. reduced strippability, than that of the WBCC with MIL-P-53022 on steel substrate. The strip rate for the SERDP Low VOC CARC is higher than that for the current CARC. Figures C-10 and C-11 indicate that the SERDP Low VOC CARC strip rates are higher than either baseline system with both primers.

### **3.2.5 Type V PMB**

The strippability data in tabulated and graphical formats for this process are found in Table C-5, and Figures C-12 and C-13, Appendix C. As may be seen in Figures C-12 and C-13, some strippability comparisons were made between SERDP Low VOC CARC colors (Grey and Green). All data for this process were developed with aluminum

substrate materials since this process is typically used for application on aluminum substrate only.

The strippability data found in Table C-5 indicate fairly clearly that the oven cured materials are tougher to strip than the UV/CON conditioned materials. Data in this table also show a very distinct difference in strippability between all of the MIL-P-23377 and MIL-P-53022 materials. The strip rates from test materials based on the MIL-P-53022 were lower by a factor of 2 or more. Once again, there are no appreciable differences seen in comparisons of UV/CON strip rates for most of the data sets.

Data presented by Figures C-12 and C-13 are fairly consistent in that both colors of the SERDP Low VOC CARC stripped more readily than either baseline system, but an overall variance with this DMB process was seen with these data in the strippability between the SERDP Low VOC CARC colors. The grey was easier to strip with the MIL-P-53022 than the green. The relationship is reversed with the MIL-P-23377 based test materials.

### **3.2.6 Stainless Steel Shot Blasting**

The strippability data in tabulated and graphical formats for this process are found in Table C-6, and Figures C-14 and C-15, Appendix C.

A comparison of the strip rates derived from oven conditioned materials, which may be found in Table C-6, does not give indication that the UV/CON conditioned materials are easier to strip with this process. In fact, the data compared over the entire range is rather close, and it may be more accurate to say there is no significant differences seen between any of the aging processes with this DMB process.

Figure C-14 depicts the strip rate data for aluminum test materials prepared with MIL-P-23377. It may be seen from this figure that SERDP Low VOC CARC strips faster than the WBCC, but while very close in strip rate to the current CARC, it has a slightly lower strip rate.

Figure C-15 presents data for two data sets, which are data from aluminum and steel substrate prepared with MIL-P-53022. Strip rates for the SERDP Low VOC CARC versus the current CARC are seen to be higher for both data sets, but this is not true in the comparison of strip rates to the WBCC materials. The strip rates determined for the WBCC materials on steel substrate are higher than those of the SERDP Low VOC CARC.

### **3.2.7 Wheat Starch Dry Media Blasting**

The strippability data in tabulated and graphical formats for this process are found in Table C-7, and Figures C-16 and C-17, Appendix C. Strippability data was not developed for any metallic substrate materials since this process is used by CCAD

exclusively on composite materials. There were no test materials conditioned by UV/CON since it was believed that the condensate phase of the cyclic exposure could easily damage the substrate material.

Strip rate data presented in Figure C-16 shows that the strippability of the SERDP Low VOC CARC was higher than seen with either baseline system based on a system with MIL-P-23377. Strip rate data presented in Figure C-17 for test materials based on MIL-P-53022 once again show a slightly higher strip rate derived from the WBCC materials when compared to the SERDP Low VOC CARC test materials test results. However, the current CARC is seen to have a lower strip rate than either the WBSS or the SERDP Low VOC CARC.

### **3.3 CARC Strippability with Chemical Depaint Processes**

Assessments of strippability of various combinations of substrate, primer, topcoat, and artificial aging were conducted on a limited basis with chemical depaint processes identified as currently in use at the several DoD maintenance operations surveyed in this study. Testing was limited due to a limited supply of test materials. In addition, several of the chemical strippers are used for either ferrous or non-ferrous materials, and not both materials. This effort was added to the Test Plan late into the project, and it was decided to conduct as much testing as feasible with the materials available. All available data has been tabulated, and is presented in Appendix D. Table D-1 lists the various processes tested for this study.

#### **3.3.1 Penetone NPX (Methylene Chloride Based) used for All Metallic Applications**

Coating system blistering was fairly rapid, and tended to proceed as smaller blisters joining together until the entire coating system lifted from the substrate. Complete strip times associated with the aluminum panels primed with MIL-P-53022 and oven aged were longer by 5 to 6 times than those seen with other material combinations tested with this chemical stripper. This particular effect was seen with all topcoats. However, the strip time required for the SERDP Low VOC CARC was greater than that of the WBCC, while less than that required for the current CARC.

All test results were within the boundaries for acceptable strip or dwell time, and with the exception of the afore mentioned variances, there are little to no differences in these data overall. Test results/observations are summarized in Table D-2, Appendix D.

#### **3.3.2 Sodium Hydroxide/Sodium Gluconate Solution (70:30 by volume) used for Ferrous Materials**

Chemical reaction with all of the coating systems with this process was very limited. None of the test samples showed complete stripping within normal operational

boundaries, but it must be remembered that this process is not intended for coatings removal. It is used for rust removal primarily, and any coatings removal is extra benefit.

Most of the data developed for this process is virtually the same with two variances seen with new SERDP Low VOC CARC samples where approximately 50% of the coating system was removed after the 24 hour dwell period. Both of these samples were UV/CON conditioned. All test results are found in Table D-3, Appendix D.

### **3.3.3 Ameratec ADL-220 (1:1 solution w/H<sub>2</sub>O) used for Ferrous Materials**

Stripping trials conducted using the specified solution, 2-hour dwell, and bath temperature cited for the RRAD process did not produce any appreciable stripping of any of the test materials. RRAD has given indications that this process is quite unpredictable, and that this result should not be construed as unusual. RRAD is currently assessing alternative methods. Test results are summarized in Table D-4, Appendix D.

### **3.3.4 Calgon EZE -545 used for Non-Ferrous Materials**

Strippability characteristics were observed to be similar to those of the Penetone NPX. This chemical stripper exhibited significantly longer complete strip times (4 to 10 times greater) with aluminum materials primed MIL-P-53022. This effect is also seen in one of the data sets based on MIL-P-23377 with oven aged test materials. Data from 5 of the 6 data sets presented also indicate that the oven aged materials are harder to strip than the UV/CON conditioned test materials. All test results for this process are summarized in Table D-5, Appendix D.

### **3.3.5 Turco 6088 Thin**

There were two different processes tested based on the Turco 6088 Thin. It is a dip tank process chemical used by both Tobyhanna AD and Red River AD, but with some differences in the process parameters. The Red River process parameters are intended to produce satisfactory stripping with a 30 minute dwell with a bath temperature of 140 °F. The Tobyhanna process permits a longer dwell (2 to 4 hours), but uses a lower bath temperature (120 °F). Test results for the Red River and Tobyhanna processes are tabulated in Tables D-6 and D-7, Appendix D, respectively.

The test results for both processes are very similar. Stripping of the SERDP Low VOC CARC is generally acceptable per individual depot criteria. There are some indications that the SERDP Low VOC CARC does not strip as readily as the WBCC topcoated materials, but since these are Army depot processes this may not be of particular significance.

There are exceptions to the above general results that are seen with the Red River AD process. These exceptions in one case may not be significant, i.e., 45 minutes for 100% stripping versus the desired 30 minutes, but the other instance resulted in stripping at



3 hours versus the desired 30 minutes. In both instances the test materials were primed with MIL-P-53022. What is more significant, however, is that the current CARC was not completely stripped after 12 hours of dwell. This effect is also seen with the Tobyhanna process in combination with MIL-P-53022 materials topcoated with MIL-C-46168.

### **3.4 CARC Strippability with Applied Light Energy Processes**

As mentioned previously, the several forms of applied light energy stripping processes assessed are currently in varying levels of development. The Flashjet<sup>TM</sup> process is production ready, and represents a technology that will be implemented at several DoD maintenance operations, including Corpus Christi AD. Since this process is at this level of technical maturity, the assessments with this process were conducted with full size test panels. On the other hand, since this process will be limited in use at CCAD to composite materials, the test materials for this process were fiberglass substrate only, with the typical primer/topcoat combinations.

It should be noted that acceptable stripping for this process was complete removal of the topcoat, with minimal primer removal. This is the standard applied by CCAD for stripping applications of this nature. All data acquired for this process is tabulated, and also presented in graphical form in Appendix E.

Assessments conducted with the two laser based stripping processes were not assessed in a production ready mode, and do not represent technology that is certain to be implemented into DoD maintenance operations during the course of this study. Materials were available to conduct fairly comprehensive assessments, but limited somewhat due to availability of test panels. As seen in the data (Appendix E), the strip rates are quite low in comparison to production stripping processes, which is partly due to the small area stripped by these processes, as well as restricted technical development. Strip rate data developed for these processes were acquired through several (6-12) discrete areas on individual test panels. Therefore, the strip rate data presented (Tables E-2 and E-3, Appendix E) for these processes are mean values derived from these smaller areas.

#### **3.4.1 FlashJet<sup>TM</sup> Xenon Flash Stripping**

Figures E-1 and E-2, Appendix E, indicate that the strip rates for this process with all of the coating systems is at a level that would easily be considered productive by most maintenance operations that involve these types of materials. This is especially pertinent for aerospace applications since strip rate is usually kept low to avoid potential substrate damage. However, the more significant point to see from these data regarding this study is that the SERDP Low VOC CARC strips more readily, or equally as in the case of WBCC with MIL-P-23377 primer, with the FlashJet<sup>TM</sup> process than either baseline system with this process.



### **3.4.2 GLC and CWA Pulsed Nd:YAG Laser Stripping**

Data for both laser stripping processes are tabulated, and presented in graphical format in Appendix E. Table E-2 and Figures E-3 through E-6 are the data developed with the General Lasertronics Corporation laser stripping process. Data developed with the Craig Walters Associates laser stripping process are presented in Table E-3, and Figures E-7 through E-10.

The results for both sets of data are very similar even though the means of coatings removal differ. This difference was evident in observations of the stripping trials. GLC laser stripping produced more vaporized material (ablative process), and the CWA laser stripping process tended to produce large pieces of coating system (laser shock) which separated from the substrate. The primary difference between the data produced by the two systems are the actual strip rate data. The GLC strip rate data tended to be higher by about an order of magnitude. Strip rate data produced by both processes tended to be a couple orders of magnitude lower than the lowest (wheat starch DMB) production process included in this study.

The strippability trends are nearly identical for both processes. Data for each process, in nearly every data set, indicates that the SERDP Low VOC CARC is more readily stripped by either laser process than either baseline coating system. This trend also holds true over the range of substrate materials, which for these processes included fiberglass test substrate.

## **4.0 CONCLUSIONS/RECOMMENDATIONS**

The overall conclusion to be reached on the basis of the CARC stripping requirements survey is that the preponderance of this work is done with some form of dry abrasive blasting. Another, somewhat obvious conclusion to be drawn from this survey is that there is a common concern pertaining to any increases of hazardous waste products associated with the SERDP Low VOC CARC. If any of the stripping processes proved to require modification, and/or to be replaced, these concerns would be paramount in any considerations for such efforts. These issues would need to be the foundation for acceptance criteria to guide development of any stripping process modifications.

CARC strippability data for the various dry media depaint processes suggests that the strippability of the SERDP Low VOC CARC should not be expected to present an adverse impact to depaint operations. The strippability data for the SERDP Low VOC CARC was varied. There were instances where the SERDP Low VOC CARC was removed at a higher strip rate, and there were instances where the strip rate was lower. There also is no clear trend of the strippability data that might be associated with a given topcoat, or any given stripping process.

The chemical strippability data suggests that stripping productivity of the SERDP Low VOC CARC using these processes is not expected to be impacted significantly. The

most significant change in strippability was exhibited by the tests conducted with a secondary stripping process (Calgon EZE-545) used by Red River Army Depot for ferrous materials. The results of the depaint requirements survey indicated that work on ferrous materials at this depot is very low in proportion to the work done with aluminum materials, which means that while there may be an impact, the impact itself may be insignificant to that operation. In addition, Red River has given indications that evaluations are being conducted of a chemical stripping process that if successful, may replace their entire current chemical stripping processes.

Strippability with the SERDP Low VOC CARC with the applied light energy processes must be considered a non-issue. No data were developed that indicate that the SERDP Low VOC CARC will present any strippability problems with these processes, and very likely with any similar processes.

The final conclusion is, given that there is no firm foundation from the data to support modifying or replacing current depaint processes to accommodate the SERDP Low VOC CARC, there will also be no need to be concerned over waste disposal. Since there are no changes in current processes seeming to be necessary, the disposal associated with these processes should not be effected.

## 5.0 References

1. "Low Volatile Organic Compound (VOC) Chemical Agent Resistant Coating (CARC)" Strategic Environmental Research & Development Program (SERDP) FY98 Annual Technical Report Project #PP 1056/78, December 1998
2. "SERDP LOW VOC CARC STRIPPABILITY", William P. Hoogsteden and Charles Cundiff, 1999 Air Force Corrosion Managers' Conference, Macon, GA
3. SERDP Low VOC CARC Removal, William P. Hoogsteden and Charles Cundiff, 1999 DOD/Industry Coatings Conference, Monterey, CA

# **APPENDIX A**

## **CARC STRIPPING SURVEY RESULTS**

**Table A-1. CARC Stripping Requirements for Several DoD Maintenance Operations**

<b>CARC NEEDS &amp; REQUIREMENTS DEFINITION PHASE</b>			
<b>Base</b>	<b>Anniston Army Depot</b>	<b>Corpus Christi Army Depot</b>	<b>Letterkenny Army Depot</b>
<b>Location</b>	Anniston, AL	Corpus Christi, TX	Chambersburg, PA
<b>Point of Contact</b>	Tony Pollard	Susan Veatch	Dennis Reed
<b>Numbers (voice &amp; fax)</b>	256/235-7071 (v)	361/961-2767 (v) 363/961-2765 (f)	717/267-8376 (v) 717/267-9299 (f)
<b>Date of Last Visit</b>	5 Sep 97	20 Jan 98	19 Nov 97
<b>1. CARC Stripping Requirements</b>	Vehicle and Artillery	Helicopters	Missiles & Heavy Equipment
<b>2. Facilities &amp; Usage (%)</b>	6 Booths Table Spinner 4 Glove Boxes 3 Dip Tanks	4 Booths 70% 10 Glove Boxes 10% 6 Dip Tanks 10% 5 Chem Areas 10%	4 Booths 1 Rotor Spinner 1 Tumbler Glove Boxes Dip Tanks
<b>3. Methods &amp; Usage (%)</b>	Blast 75% Chemical 25%	Blast 80% Chemical 20%	Blast 85% Chemical 15%
<b>3a. Media &amp; Usage (%)</b>	Steel Shot 0.5% Green Lightening 60% Black Beauty 30% Walnut 7% Glass Bead 2% Aluminum Oxide 0.5%	Type II 10% Type V 60% Wheat Starch 10%	Walnut = primary Garnet PMB Steel Shot Glass
<b>3b. Chemicals &amp; Usage (%)</b>	Penetone NPX 100%	Methylene Chloride 10% N-Methyl Pyrrolidone(NMP) /Diethylene glycol b-butyl ether 10%	Sodium Hydroxide Turco 6088A
<b>4. Substrates &amp; Portion of Workload (%)</b>	Steel 75% Aluminum 25%	Aluminum (0.016-0.064) Titanium (>0.064) Magnesium (>0.064) Stainless Steel (>0.064) Composites	Steel = typically > 1/8" thick 5000 series Al 7000 series Al Honeycomb Composites
<b>5. Acceptance Criteria</b>	Visual Inspection (white metal)	Composites = no broken fibers Al = Almen $\Delta h \leq 2$ mils	TBD
<b>6. Production</b>	Not Quantifiable	FY98 4358 manhrs/yr budgeted, no future data supplied	TBD
<b>7. Environmental Concerns</b>	Hazardous Waste Disposal	Eliminate Methylene Chloride, reduce spent PMB and Wheat Starch waste products	Pennsylvania EPA has closely scrutinized depot waste disposal and compliance
<b>8. Needs</b>	Increasing workload will allow no reduced throughput	Improved facilities	Chemical stripping needed for geometries not easily stripped by blasting processes
<b>9. Technical Efforts</b>	Shift to more durable media & methylene chloride replacement	Tested various dry and wet stripping techniques	TBD
<b>10. Specifications/Pertinent Data</b>	None provided	TO 1-1-8, ATCOM AED A1116B (Army General PMB Techniques), NAVAIR 01-1A-509 (Aircraft weapons cleaning and corrosion control), D6-56993 (Wheat Starch Blasting of Composites), CCAD Process Standards A.05, A.10, A.12, A.21, & C.08) Various documents for composite repair	TBD
<b>11. Miscellaneous Issues</b>	None	Recycling for PMB. PMB on thin Aluminum	Better adhesion on rough surface w/o chromate conversion

**Table A-1. CARC Stripping Requirements for Several DoD Maintenance Operations**

<b>CARC NEEDS &amp; REQUIREMENTS DEFINITION PHASE</b>			
<b>Base</b>	<b>Red River Army Depot</b>	<b>Tobyhanna Army Depot</b>	<b>Sacramento ALC</b>
<b>Location</b>	Texarkana, TX	Scranton, PA	Sacramento, CA
<b>Point of Contact</b>	Mike Starkes	Ron Scarnulis	Ed White
<b>Numbers (voice &amp; fax)</b>	903/334-2601 (v) 903/334-3650 (f)	570/895-8223 (v) 570/895-8412 (f)	916/643-4886(v)
<b>Date of Last Visit</b>	3 Dec 97	18 Nov 97	23 Nov 97
<b>1. CARC Stripping Requirements</b>	1996 total gallons applied: 8307 one part, 3807 two part 1997 lower (Numbers not in.) 1998 50% of 1996 levels (Bradley Fighting Vehicle)	Mil-C-53039, Mil-C-46168, Mil-C-22750, Mil-P-53030, MIL-C-53072, DOD-P-15328 (Electronic Components, Vans & Shelters)	Vans & Shelters for Ground Radar
<b>2. Facilities &amp; Usage (%)</b>	7 Booths 90% 11 Rotor Spinners/tumblers 3% 11 Glove Boxes 2% 10 Dip Tanks 5%	3 Booths 20% 1 Rotor Spinner 20% 1 Tumbler 20% Glove Boxes 20% Dip Tanks 20%	Single Booth 100%
<b>3. Methods &amp; Usage (%)</b>	Blast 95% Chemical 5%	Blast 90% Chemical 10%	Blast 100%
<b>3a. Media &amp; Usage (%)</b>	Steel Shot 75% Garnet 24% Walnut 1%	Zirconia Alumina 65% Steel Shot 35%	PMB Type II 80% Handsanding 20%, touchup
<b>3b. Chemicals &amp; Usage (%)</b>	Turco 6088A-Thin 75% (Primary) Calgon EZE-545 (Secondary) Ameratec ADL-220 25%	Turco 6088A-Thin 90% Turco 6813-LO 10% (Formic Acid/Benzyl Alcohol)	
<b>4. Substrates &amp; Portion of Workload (%)</b>	5000 series Al, 1-1.5", 1/8" thick minimum 95% Various Steels 5%	2024, 5052, 6061, 7075 Al 65% (0.03-0.375") Steel 30% (0.03-0.375") Composites 5% (0.06-0.375")	5000 series Al 50% Steel 50%
<b>5. Acceptance Criteria</b>	Surface finish, desirable/acceptable at 2-4 $\mu$ m	Mil-C-53072	Visual Evaluation for Damage such as Panel Warpage and Good Surface Finish
<b>6. Production</b>	Rough Estimates Al = 95 manhrs/shift (75 for future) Steels = 5 manhrs/shift (5 for future)	Unavailable	Unavailable
<b>7. Environmental Concerns</b>	Potential reduction in hexavalent chromium exposure levels from OSHA may affect cleaning methods.	Decreasing OSHA limits for Cadmium and PA EPA	California EPA maintains close scrutiny on base discharge
<b>8. Needs</b>		Remove CARC from thin skin effectively & economically while minimizing hazardous wastes	
<b>9. Technical Efforts</b>	Ongoing work with venders.	None	None
<b>10. Specifications/Pertinent Data</b>	There are some available but most refer to the 2-4 $\mu$ m surface finish	None	None
<b>11. Miscellaneous Issues</b>	None	None	None

**Table A-1. CARC Stripping Requirements for Several DoD Maintenance Operations**

<b>CARC NEEDS &amp; REQUIREMENTS DEFINITION PHASE</b>		
<b>Base</b>	<b>Marine Corps Logistics Base, Albany, Georgia</b>	<b>Marine Corps Logistics Base, Barstow, California</b>
<b>Location</b>	Albany, GA	Barstow, CA
<b>Point of Contact</b>	Ron Vargo	Skip Schnur
<b>Numbers (voice &amp; fax)</b>	912/439-5503, 5504 (v) 912/439-6824 (f)	760/577-7295 (v) 760/577-7294 (f)
<b>Date of Last Visit</b>	8 Oct 97	3 Nov 97
<b>1. CARC Stripping Requirements</b>	Remove CARC system from items of equipment in preparation for other work to be performed as required Paint removal is accomplished in accordance with instructions as appropriate (Heavy Equipment)	Customer driven since much of the workload is for other DoD functions (Primarily Heavy Equipment)
<b>2. Facilities &amp; Usage (%)</b>	5 Booths 75% 1 Tumble Blasters 4% 2 Rotor Spinners 17%	2 Booths 1 Table Spinner 1 Rotor Spinner 1 Tumbler 2 Glove Boxes
<b>3. Methods &amp; Usage (%)</b>	Blast 100%	Blast 90% Chemical 10%
<b>3a. Media &amp; Usage (%)</b>	PMB 10% Garnet 69% Steel Shot/Grit 20% Glass Bead 1%	Steel Shot 50 % Garnet 30% Type V PMB 20%
<b>3b. Chemicals &amp; Usage (%)</b>	N/A	Sodium Hydroxide 60% Sodium Glutamate 40%
<b>4. Substrates &amp; Portion of Workload (%)</b>	Steel 60% Aluminum 35% Fiberglass 2% Wood 1% Rubber 2%	Steel Aluminum Composites
<b>5. Acceptance Criteria</b>	Varies and is detailed in SOW for each product	Customer Determined
<b>6. Production</b>	Current requirement in Cost Center of 657 manhours per month as: Steel Parts = 500hrs Aluminum Parts = 150hrs Rubber Parts = 5hrs Fiberglass Parts = 1hr Wood = 1hr Future requirements cannot be easily quantified	Not Made Available
<b>7. Environmental Concerns</b>	Recycle, waste reduction, cost, release risk.	Recycling of waste products & California EPA close scrutiny
<b>8. Needs</b>	Currently only blast capable. Need chemical method to reduce risk of damage to smaller components.	Improved chemical strippers that are environmentally benign.
<b>9. Technical Efforts</b>	Study was done to replace Methylene Chloride with NMP Samples of ferrous and nonferrous CARC painted material sent to 8 chemical stripper companies in 1997 High pressure water blasting investigated with favorable results	Process Containment (i.e., air emissions)
<b>10. Specifications/Pertinent Data</b>	None	TM 3080-50
<b>11. Miscellaneous Issues</b>	None	Better adhesion on rough surface w/o chromate conversion

## **Appendix B**

### **CARC STRIPPABILITY TEST PLAN**

# **CARC STRIPPABILITY TEST PLAN**

by

R. Leverette  
Southwest Research Institute

Prepared for  
AFRL/MLSS

August 1998

Approved:

C.H. Cundiff  
Project Manager



# CARC STRIPPABILITY TEST PLAN

## 1.0 Scope

This test plan was written to support the TRW/Southwest Research Institute (SwRI) Coatings Technology Stripping Reliability/Maintainability Improvement Project. It is designed to develop a valid means to determine the effective stripping capability of current depaint processes with a new low VOC chemical agent resistant coating (CARC). This new SERDP Low VOC CARC is being developed by Strategic Environmental Research and Development Program (SERDP).

The primary goals for this project were first outlined in the SwRI Project Plan "Coatings Technology Stripping Reliability/Maintainability Improvement."

These goals include:

1. Testing of existing stripping processes/methods with the SERDP Low VOC CARC materials to determine if further testing and/or development is required to meet R&M goals and to compare against current CARC materials.
2. Optimization of existing and/or newly developed stripping technologies to comply with R&M goals.
3. Stripping process materials characterization testing as required for qualification of modified or new stripping processes. (The exact scope of this effort will be substrate material and specific application dependent.)

## 2.0 Equipment/Resource Requirements and Schedule

### 2.1 Equipment

The following equipment will be needed to conduct the tests:

Paint Booth  
Curing Oven  
QUV

Test Facilities (Baseline and comparison depaint testing will be conducted at various DOD Installations), and laboratory facilities for chemical stripping process testing.

## 2.2 Resources

To conduct the tests, sufficient quantities of the following materials will be required to prepare the test panels:

- 1010 alloy steel of 0.063" thickness to make 60 2'x2' test panels
- 2024-T3 alloy aluminum of 0.063" thickness to make 120 2'x2' test panels
- 2024-T3 alloy aluminum of 0.032" thickness to make 64 2'x2' test panels
- Fiberglass/Epoxy 8-ply 0.062" thickness to make test panels to make 72 1'x2' test panels
- Zinc-Phosphate pre-treatment in accordance with (IAW) T-T-C 490
- Chromate Conversion Coating IAW TO 1-1-8
- Primer MIL-P-53022
- Primer MIL-P-23377, Type 1, Class C
- Topcoat MIL-C-46168D CARC 383 Green (Color #34094)
- Topcoat MIL-C-29475 Water Borne Camouflage Coating (WBCC) 383 Green (Color #34094)
- Topcoat SERDP Low Volatile Organic Compounds (VOC) CARC - Air Force Light Grey (Color # 36251)
- Topcoat SERDP SERDP Low VOC CARC - Navy Green (Color # 383)
- Penetone Penstrip NPX chemical stripper
- Calgon EZE 545 chemical stripper
- Ameritech ADL-220 chemical stripper
- Altochem Turco 6088A-Thin chemical stripper.

## 2.3 Schedule

The test panel preparation and field level testing phases of this project will be conducted over a one year period (or less) contingent upon acceptance of this test plan and the availability of a surface preparation room, paint booth, and depaint facilities at field test sites. The proposed schedule is shown in Figure B-1.

In general, test panels will be prepared, coated, and allowed to dry for a minimum of seven days. The test panels will be artificially aged by one of two processes, ultra-violet/condensate (UV/CON) chamber or by elevated temperature.

## 3.0 **Preparation Chart and Testing Matrix**

The specific parameters for test material preparation and test matrix details are given below. The test matrix has been designed to accomplish the goal of maximizing the number of panels tested at the minimum number of test facilities.

### Table B-3.1. Test Panel Preparation Chart

Substrate		Alloy	Thickness	Pre-Treatment	Primer	Topcoat	Cure	# Panels	
S1	Steel	1010	0.063 in	Zinc-phosphate (T-T-C 490)	MIL-P-53022	MIL-C-46168D	QUV	15	
	Steel	1010	0.063 in	Zinc-phosphate (T-T-C 490)	MIL-P-53022	MIL-C-46168D	Oven	5	
S2	Steel	1010	0.063 in	Zinc-phosphate (T-T-C 490)	MIL-P-53022	MIL-C-29475	QUV	15	
	Steel	1010	0.063 in	Zinc-phosphate (T-T-C 490)	MIL-P-53022	MIL-C-29475	Oven	5	
S3	Steel	1010	0.063 in	Zinc-phosphate (T-T-C 490)	MIL-P-53022	Low VOC CARC	QUV	15	
	Steel	1010	0.063 in	Zinc-phosphate (T-T-C 490)	MIL-P-53022	Low VOC CARC	Oven	5	
								Total	60
A1	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	MIL-C-46168D	QUV	15	
	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	MIL-C-46168D	Oven	5	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	MIL-C-46168D	QUV	6	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	MIL-C-46168D	Oven	2	
A2	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	MIL-C-46168D	QUV	15	
	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	MIL-C-46168D	Oven	5	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	MIL-C-46168D	QUV	6	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	MIL-C-46168D	Oven	2	
A3	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	MIL-C-29475	QUV	15	
	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	MIL-C-29475	Oven	5	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	MIL-C-29475	QUV	6	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	MIL-C-29475	Oven	2	
A4	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	MIL-C-29475	QUV	15	
	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	MIL-C-29475	Oven	5	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	MIL-C-29475	QUV	6	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	MIL-C-29475	Oven	2	
A5	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	Low VOC CARC	QUV	15	
	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	Low VOC CARC	Oven	5	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	Low VOC CARC	QUV	6	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	Low VOC CARC	Oven	2	
A6	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	Low VOC CARC	QUV	15	
	Aluminum	2024-T3	0.063 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	Low VOC CARC	Oven	5	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	Low VOC CARC	QUV	6	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	Low VOC CARC	Oven	2	
								Total	168
N1	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	LV.Carc-Navy Color	QUV	6	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-53022	LV.Carc-Navy Color	Oven	2	
N2	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	LV.Carc-Navy Color	QUV	6	
	Aluminum	2024-T3	0.032 in	CRO <sub>4</sub> conv (TO 1-1-8)	MIL-P-23377, Type 1, Class C	LV.Carc-Navy Color	Oven	2	
								Total	16
F1	Fiberglass	8-ply	0.062in	N/A	MIL-P-53022	MIL-C-46168D	Oven	12	
F2	Fiberglass	8-ply	0.062in	N/A	MIL-P-23377, Type 1, Class C	MIL-C-46168D	Oven	12	
F3	Fiberglass	8-ply	0.062in	N/A	MIL-P-53022	MIL-C-29475	Oven	12	
F4	Fiberglass	8-ply	0.062in	N/A	MIL-P-23377, Type 1, Class C	MIL-C-29475	Oven	12	
F5	Fiberglass	8-ply	0.062in	N/A	MIL-P-53022	Low VOC CARC	Oven	12	
F6	Fiberglass	8-ply	0.062in	N/A	MIL-P-23377, Type 1, Class C	Low VOC CARC	Oven	12	
								Total	72

**Table B-3.2. Stripping Processes Assessments per Substrate**

Substrate	Stripping Processes
Steel	Garnet, Steel Shot, PMB Type II, Walnut Hull, Zirconia Alumina, Penetone NPX, ADL-220, and Turco 6088A-Thin
Aluminum	Garnet, Steel Shot, PMB Type II & V, Walnut Hull, Zirconia Alumina, Wheat Starch, Turco 6088A-Thin, Calgon EZE-545, and Penetone NPX
Fiberglass	PMB Type V, Wheat Starch, and Flash Jet

**Table B-3.3. Strippability Test Matrix/Facility (Site)**

Base	Proposed Test Date	Process	Substrate
Letterkenny/ Tobyhanna Army Depots	October 19, 1998	Walnut	Steel & Aluminum
	November 9, 1998	Zirconia Alumina	Steel & Aluminum
Albany Marine depot	January 25, 1999	Steel Shot	Steel & Aluminum
		Garnet	Steel & Aluminum
	February 15, 1999	PMB Type V	Aluminum & Fiberglass
Corpus Christi Army Depot	November 23, 1998	Wheat Starch	Aluminum & Fiberglass
Boeing, St. Louis Division	March 29, 1999	Flash Jet	Fiberglass
McClellan AFB	December 15, 1998	PMB Type II	Steel & Aluminum
CTIO Dayton	September 16, 1998 (prelim)	Chemical	Steel & Aluminum
	November 16, 1998 (complete)		

## 4.0 Panel Preparation General Procedures

### 4.1 Panel Preparation

Application of coatings systems and pre-application surface preparations will be IAW the following:

1. Steel test panels will be prepared and Zinc-phosphate pre-treated IAW T-T-C 490D. Primers and Topcoats will be applied IAW the applicable MIL-SPECS listed in the Test Panel Preparation Chart of Section 3.1.
2. Aluminum test panels will be prepared IAW TO 1-1-691. Chromate Conversion pre-treatment will be applied IAW TO 1-1-8. Primers and Topcoats will be applied IAW the applicable MIL-SPECS listed in the Test Panel Preparation Chart of Section 3.1.
3. Fiberglass test panels will be prepared IAW MIL-I-24768/27 GEE-F. Primers and Topcoats will be applied IAW the applicable MIL-SPECS listed in the Test Panel Preparation Chart of Section 3.1.

### 4.2 Panel Aging

All test panels will undergo accelerated aging by one of two methods. Procedures for this accelerated aging are as follows:

1. Test panels undergoing UV/CON aging will be conditioned for 40-12 hour cycles of UV light exposure followed by a period of water condensate exposure. Each 12 hour cycle will comprise an  $8 \pm 0.25$  hours UV exposure @  $70^\circ \pm 2^\circ$  C, followed by a  $4 \pm 0.25$  hours condensate exposure @  $50^\circ \pm 2^\circ$  C. UV exposure will be with UVB 313 bulbs, with an irradiance of  $0.63 \text{ W/m}^2$ .
2. Test panels undergoing elevated temperature aging will be conditioned in an oven at  $210^\circ \pm 2^\circ$  F for  $96 \pm 0.25$  hours.

## 5.0 Strippability Test Procedures

Dry media depaint processes will be applied by qualified operators IAW the standard operating procedures for the removal of the current CARC from each substrate for each process listed in the Test Site Utilization Chart of Section 3.3. In order to eliminate variables that could be introduced by multiple operators, all testing will be scheduled in such a fashion that one operator will be able to complete the test during a single shift. In addition, each operator will be briefed on the tests to be conducted. During this briefing, it is important that the operator understand the importance of maintaining standoff distance, strip rate, and angle of impingement as consistent as possible. The intent of this measure will be to mitigate possible effects resulting from operator related variables, and provide a consistency of application of the blast process so that confident comparisons can be made between individual test panels.

After stripping each panel, the following data will be recorded: strip rate, standoff distance, angle of impingement, maximum flow rate, pressure, nozzle parameters, and overall quality (or effectiveness) of the stripping process. This data will be recorded in a Lab Record Book. This data will be used as the basis for comparison between the baseline material (existing CARC) and the sample material (SERDP Low VOC CARC).

Chemical depaint processes will be applied by CTIO personnel IAW the standard operating procedures specified by each base for the removal of the current CARC from each substrate for each process listed in the Test Site Utilization Chart of Section 3.3. Test specimens for these tests will be materials cut from larger strippability test panels to ensure that there is consistency between these test materials, and those to be used for strippability testing with other depaint processes. Chemical strippability data sets will be comprised of a minimum of three samples of each combination of coating system and substrate materials included in the strippability evaluation, with the exception of fiberglass substrate materials.

After stripping each panel, the following data will be recorded: time to initial bubbling of the coating system, and the time to complete removal of the coating system. This data will be recorded in a Lab Record Book. This data will be used as the basis for comparison between the baseline material (existing CARC systems) and the sample material (SERDP Low VOC CARC).

## **6.0 Adhesion Testing**

The adhesion of each coating system used for evaluation of the test matrix will be characterized by use of the Modified Patti-Test method. The Modified Patti-Test method was developed at SwRI and will be performed IAW ASTM D4541, and will be performed following the procedures detailed in CTIO SOP-DRY-11. Adhesion tests will be conducted on witness panels that will be coated concurrently with test panels intended for use in the test matrix evaluation. Adhesion characterization will be based on mean adhesion values derived from measurements consisting of three measurements from each witness panel. Each coating system will have three witness panels for these measurements, which means the mean adhesion value will be based on a minimum of nine distinct measurements.

The Modified Patti-Test method will use test apparatus rings adhesively bonded to the coating system, and then allowed to cure overnight (minimum of 12 hours) before adhesion testing. In order to improve the efficiency of this method, a vacuum chuck may be used to restrain the sample during measurement.

## **7.0 Dry Film Thickness Measurements**

Dry film thickness measurements (DFTM) will be made on each test panel per CTIO SOP-DRY-02. Nine DFTM are to be made on each test panel for the primer and primer+topcoat conditions. The nine individual DFTM per test panel will be made in a symmetric array. Each test panel will have a registration mark placed on the rear (unpainted) surface to define the orientation of the test panel for DFTMs. This mark will define the upper left corner of the test panel. DFTM location identification for data

recording will be numbered 1 through 9 in a clockwise fashion, with location #1 as the measurement location adjacent to the registration marking.

## **8.0 Data Acquisition, Recording, and Quality Assurance**

All data will be recorded on Data Sheets that are in compliance with the data requirements listed below for specific portions of this project. In addition, a Paint Report will be completed for each batch of panels coated with a specific primer and topcoat. All data acquired for this, and subsequent matrix development efforts will be placed in Lab Record Books, which will be made available to the Project Manager as needed. Any observations, suggestions, or comments derived from these efforts will also be recorded in the Lab Record Books used for this project.

### **8.1 Dry Film Thickness Measurement Data**

Record DFTM for each location measured on each test panel. Also determine and record the statistical mean and standard deviation values for each data set. A data set will consist of the measurements for each panel.

### **8.2 Coatings Adhesion Data**

Record all adhesion data for the complete coating system as represented by witness panels prepared concurrently with the test panels. Other data to be recorded include the mean value for each panel tested, and mode of coating failure.

### **8.3 Stripping Effectiveness Assessment Data**

Record the strip rate, standoff distance, angle of impingement, maximum flow rate, pressure, nozzle parameters, and overall quality (or effectiveness) of the stripping process.

### **8.4 Quality Assurance**

SwRI Quality Assurance is to ensure that the equipment required for this study have the appropriate calibration certificates as required. SwRI Quality Assurance will also ensure that these calibration certificates remain valid throughout the period that this study is conducted.

**If comparison analysis of the data yielded by this plan finds that a process needs to be modified or a new process must be introduced in order to meet production requirements, this test plan will be amended to include additional testing and qualification procedures for modified or new processes.**

## **APPENDIX C**

### **CARC STRIPPABILITY DATA FOR DRY MEDIA BLASTING PROCESSES**

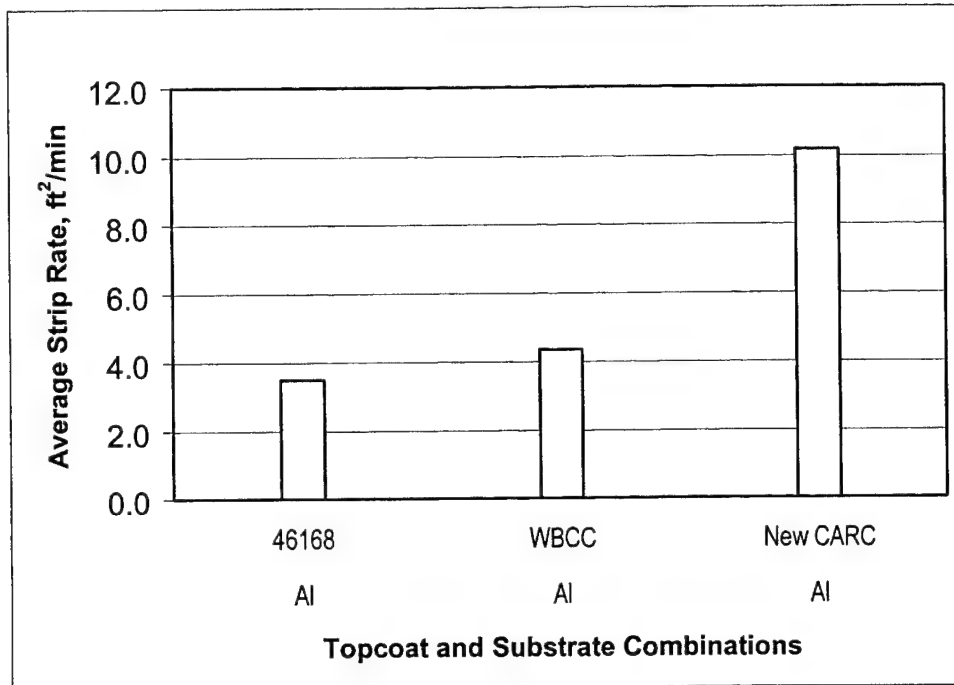


**Table C-1. Letterkenny Army Depot Walnut Hull Strippability Data**

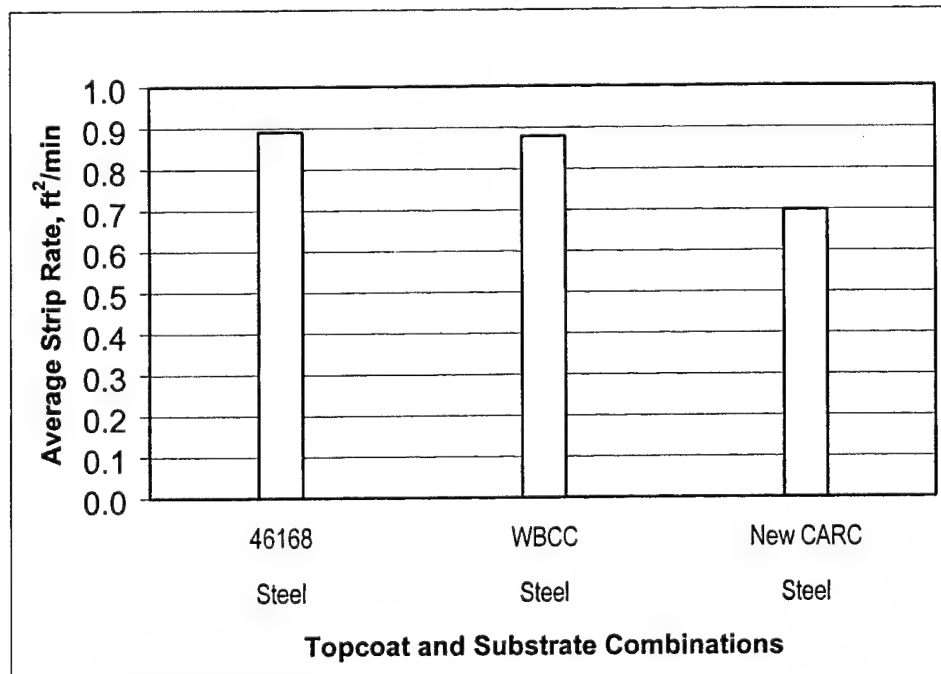
SUBSTRATE	PRIMER	TOP COAT	Age/Cure	Strip Rate, ft <sup>2</sup> /min	Set Avg, ft <sup>2</sup> /min	Notes
AL	MIL-P-53022	MIL-C-46168	UV-B	2.00	1.77 <sup>1</sup>	primer left on
AL	"	"	UV-B	1.86		primer left on
AL	"	"	UV-B	1.87		
AL	"	"	Oven <sup>2</sup>	1.37		primer left on (removal 0.35ft <sup>2</sup> /min)
AL	MIL-P-23377	MIL-C-46168	UV-B	3.21	3.50	
AL	"	"	UV-B	3.58		
AL	"	"	UV-B	3.79		
AL	"	"	Oven	3.45		
AL	MIL-P-53022	MIL-C-29475	UV-A	2.86	3.00 <sup>1</sup>	primer left on (removal 0.42ft <sup>2</sup> /min)
AL	"	"	UV-B	3.34		primer left on
AL	"	"	UV-B	3.16		primer left on (removal 0.59ft <sup>2</sup> /min)
AL	"	"	Oven	2.65		primer left on (removal 0.35ft <sup>2</sup> /min)
AL	MIL-P-23377	MIL-C-29475	UV-B	3.55	4.35	
AL	"	"	UV-A	4.15		
AL	"	"	UV-A	4.98		
AL	"	"	UV-B	4.72		
AL	"	"	Oven	4.38		
AL	MIL-P-53022	Low VOC CARC	UV-B	1.68	1.93	
AL	"	"	UV-B	1.76		little primer left behind
AL	"	"	UV-A	2.76		
AL	"	"	Oven	1.52		primer left on
AL	MIL-P-23377	Low VOC CARC	UV-A	11.06	10.19	Strip rate w/o Ov = 11.94ft <sup>2</sup> /min
AL	"	"	UV-B	12.30		
AL	"	"	UV-B	12.44		
AL	"	"	Oven	4.95		
ST	MIL-P-53022	MIL-C-46168	UV-B	0.86	0.89	
ST	"	"	UV-B	1.08		≈ 1/2 test area (timer). Good prim/tc adhesion
ST	"	"	UV-B	1.03		
ST	"	"	Oven	0.60		
ST	MIL-P-53022	MIL-C-29475	UV-A	0.72	0.88	
ST	"	"	UV-A	0.74		
ST	"	"	UV-B	1.23		
ST	"	"	UV-B	0.96		topcoat separated from primer
ST	"	"	Oven	0.75		
ST	MIL-P-53022	Low VOC CARC <sup>1</sup>	UV-B	0.47	0.70	
ST	"	"	UV-B	0.72		good prim/tc adhesion
ST	"	"	UV-B	0.59		
ST	"	"	Oven	1.01		

1 - Average based on topcoat stripping only.

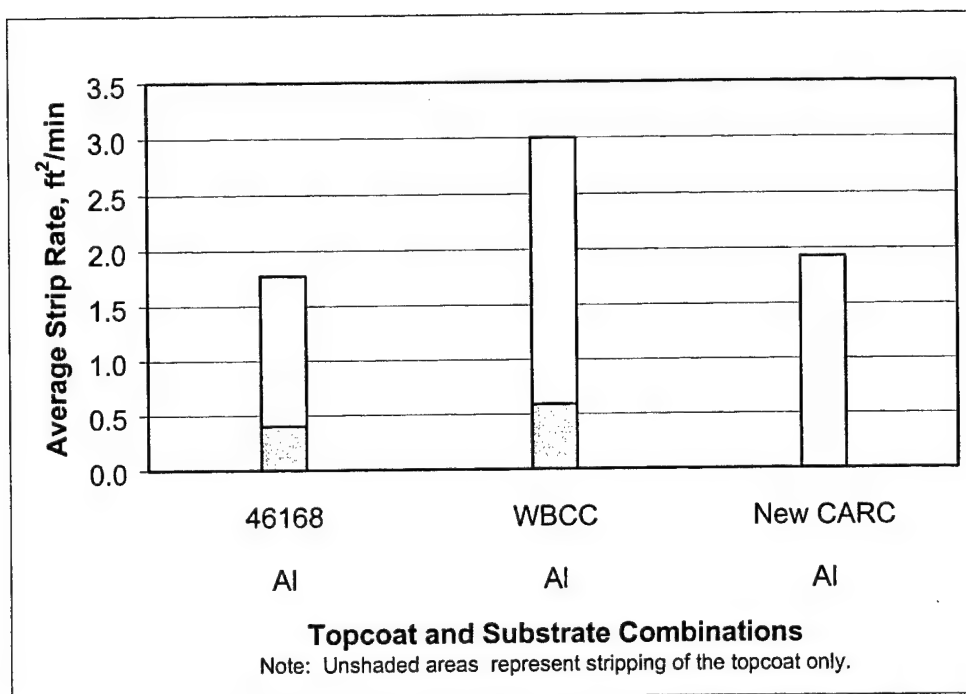
2 - Oven cure consists of 7 day minimum room temperature cure, followed by 96 hours at 210°F.



**Figure C-1. Letterkenny Walnut Hull DMB Strippability with MIL-P-23377 Primer System**



**Figure C-2. Letterkenny Walnut Hull DMB Strippability with MIL-P-53022 Primer System**



**Figure C-3. Letterkenny Walnut Hull DMB Strippability  
with MIL-P-53022 Primer**

Table C-2. Tobyhanna Zirconia Alumina Strippability Data<sup>7</sup>

SUBSTRATE	PRIMER	TOP COAT	Age/Cure	Strip Rate, ft <sup>2</sup> /min	Set Avg, ft <sup>2</sup> /min	Notes
AL	MIL-P-53022	MIL-C-46168	UV-B	0.81	0.91	1st machine
AL	"	"	UV-B	0.93		2nd machine
AL	"	"	UV-B	1.01		2nd machine
AL	"	"	Oven	0.88		2nd machine
AL	MIL-P-23377	MIL-C-46168	UV-B	0.79	0.78	1st machine
AL	"	"	UV-B	0.80		2nd machine
AL	"	"	UV-B	0.77		1st machine
AL	"	"	Oven	0.75		2nd machine
AL	MIL-P-53022	MIL-C-29475	UV-B	0.95	1.01	1st machine
AL	"	"	UV-B	0.95		2nd machine
AL	"	"	UV-B	1.05		2nd machine
AL	"	"	Oven	1.07		2nd machine
AL	MIL-P-23377	MIL-C-29475	UV-B	0.84	0.87	1st machine
AL	"	"	UV-B	0.86		1st machine
AL	"	"	UV-B	0.85		1st machine
AL	"	"	Oven	0.93		Vacuum system loss for 30 sec. 2nd machine.
AL	MIL-P-53022	Low VOC CARC	UV-B	0.53	0.64	1st machine
AL	"	"	UV-B	0.66		1st machine
AL	"	"	UV-B	0.76		2nd machine
AL	"	"	Oven	0.59		2nd machine
AL	MIL-P-23377	Low VOC CARC	UV-B	1.12	0.99	? +10-15 sec. 1st machine.
AL	"	"	UV-B	1.40		T/C came off in large chunks. 2nd machine.
AL	"	"	UV-B	0.80		1st machine
AL	"	"	Oven	0.64		T/C came off before primer. 2nd machine.
ST	MIL-P-53022	MIL-C-46168	UV-B	0.71	0.75	2nd machine.
ST	"	"	UV-B	0.75		2nd machine.
ST	"	"	UV-B	0.84		2nd machine.
ST	"	"	Oven	0.71		1st machine
ST	MIL-P-53022	MIL-C-29475	UV-B	0.72	0.69	1st machine
ST	"	"	UV-B	0.64		T/C lifted off primer. 2nd machine.
ST	"	"	UV-B	0.71		1st machine
ST	"	"	Oven	0.67		2nd machine.
ST	MIL-P-53022	Low VOC CARC <sup>1</sup>	UV-B	0.81	0.78	2nd machine.
ST	"	"	UV-B	0.94		2nd machine.
ST	"	"	UV-B	0.68		1st machine
ST	"	"	Oven	0.69		2nd machine.

1 - Navy color.

<sup>7</sup> Please note any references to "Navy color" seen with data tables is the WBCC 383 Green topcoat.

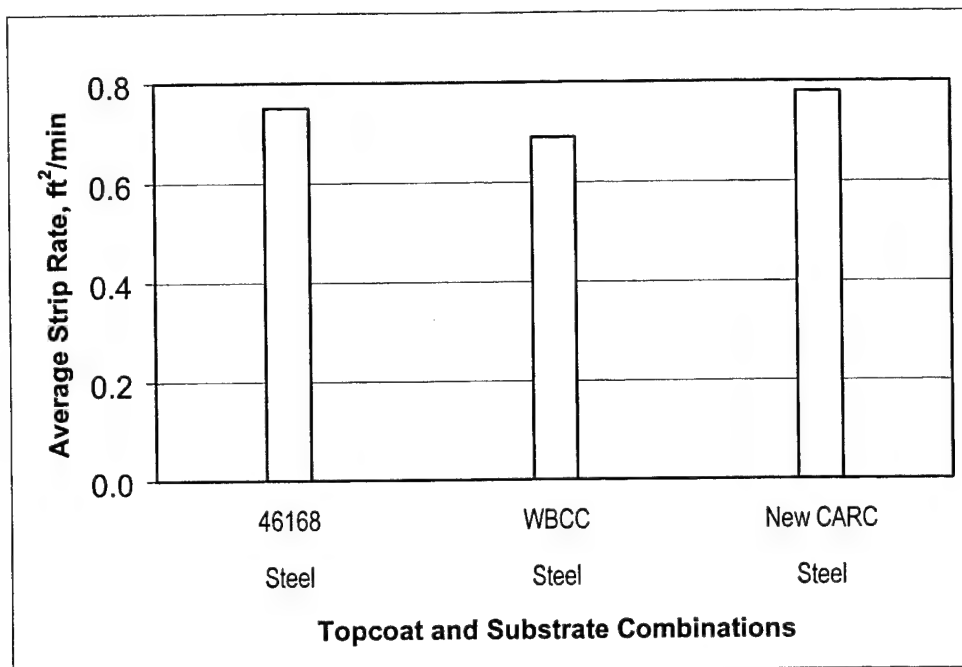


Figure C-4. Tobyhanna Alumina Zirconia DMB Strippability with MIL-P-53022 Primer

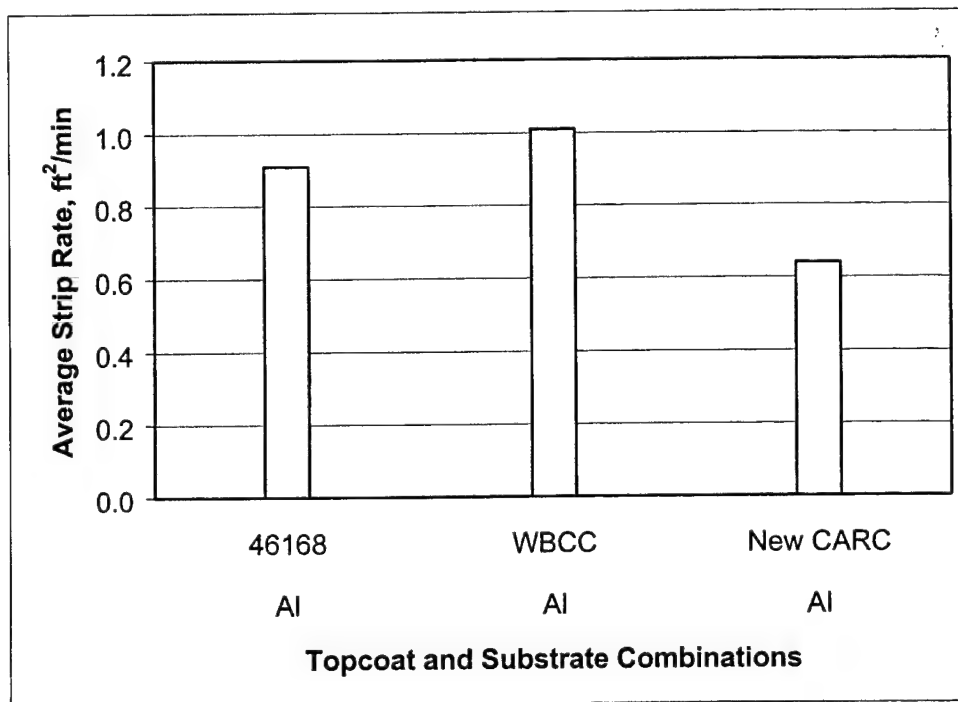
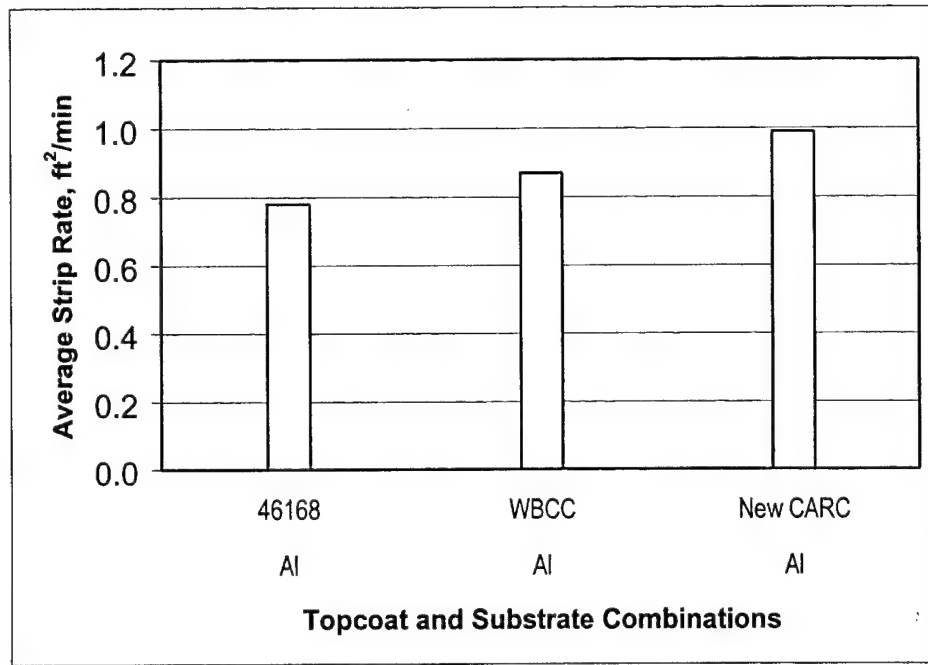


Figure C-5. Tobyhanna Alumina Zirconia DMB Strippability with MIL-P-53022 Primer

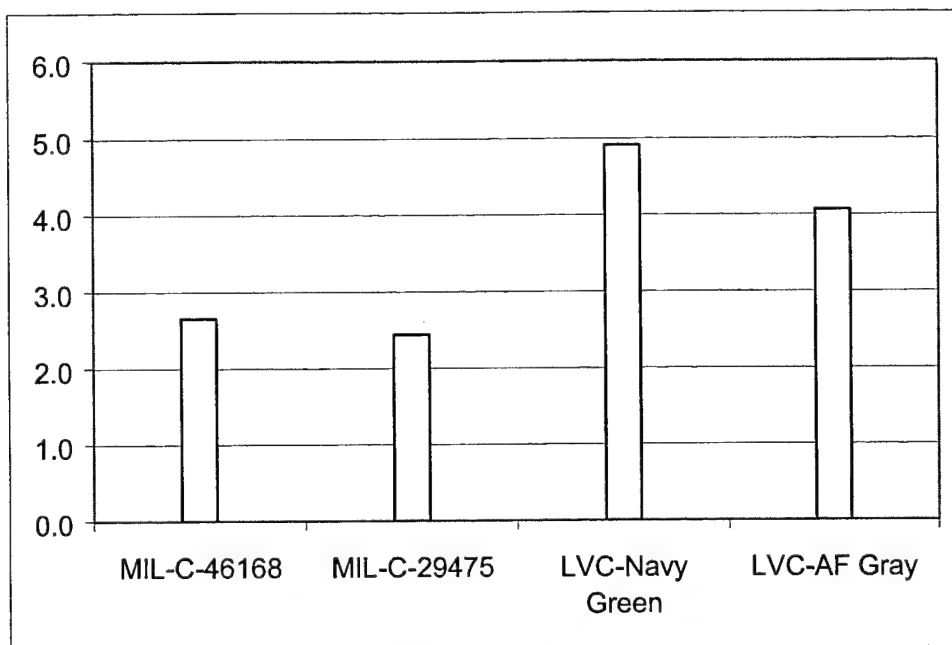


**Figure C-6. Tobyhanna Alumina Zirconia DMB Strippability with MIL-P-23377 Primer**

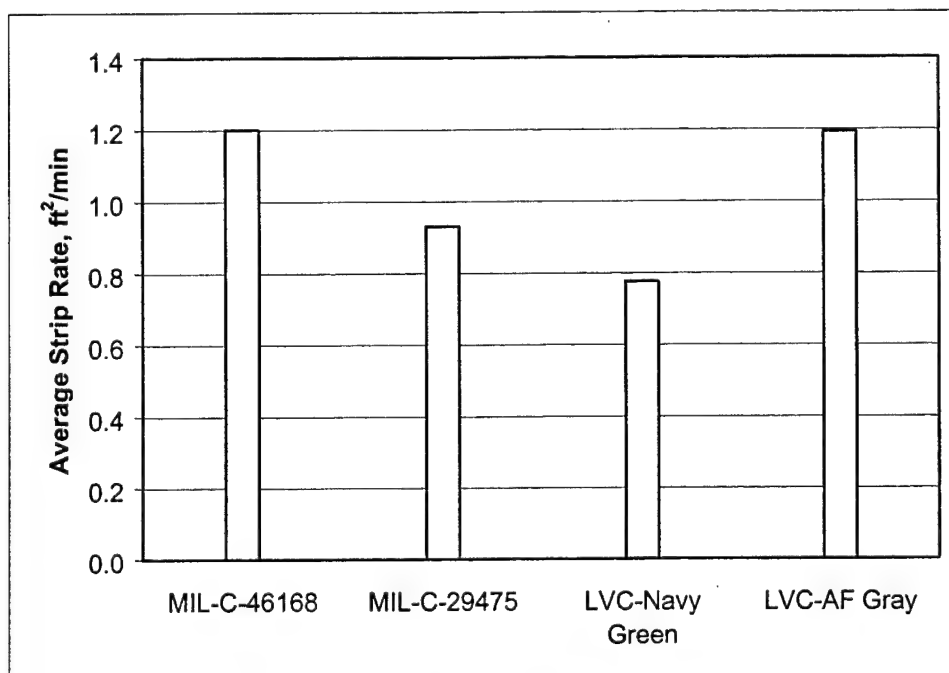
**Table C-3. Marine Corps Logistics Base-Albany Type II DMB Process Strippability Data**

SUBSTRATE	PRIMER	TOP COAT	Age/Cure	Strip Rate, ft <sup>2</sup> /min	Avg ft <sup>2</sup> /min	Notes
AL	MIL-P-53022	MIL-C-46168	UV-B	1.69	1.20	
AL	"	"	UV-B	1.40		
AL	"	"	UV-A	1.11		
AL	"	"	UV-A	1.24		
AL	"	"	Oven	0.57		
AL	MIL-P-53022	MIL-C-29475	UV-B	1.22	0.93	5% TC remained and subtracted from total area.
AL	"	"	UV-B	0.79		
AL	"	"	UV-A	0.99		
AL	"	"	UV-A	1.06		
AL	"	"	Oven	0.61		
AL	MIL-P-53022	LVC-Navv Green	UV-B	0.86	0.78	
AL	"	"	UV-B	1.00		
AL	"	"	UV-A	0.74		
AL	"	"	UV-A	0.68		
AL	"	"	Oven	0.61		
AL	MIL-P-53022	LVC-AF Gray	UV-B	1.55	1.19	5% TC remained and subtracted from total area.
AL	"	"	UV-B	1.15		10% TC remained and subtracted from total area.
AL	"	"	UV-A	1.02		
AL	"	"	Oven	1.31		
AL	"	"	UV-A	0.95		2% TC remained and subtracted from total area.
AL	MIL-P-23377	MIL-C-46168	UV-B	2.07	2.65	
AL	"	"	UV-B	3.43		
AL	"	"	UV-A	2.84		
AL	"	"	UV-A	3.43		
AL	"	"	Oven	1.49		2% TC remained and subtracted from total area.
AL	MIL-P-23377	MIL-C-29475	UV-B	2.43	2.44	
AL	"	"	UV-B	na		Missed Data Point
AL	"	"	UV-A	na		Missed Data Point. ~20-30sec
AL	"	"	UV-A	2.43		
AL	"	"	Oven	2.47		
AL	MIL-P-23377	LVC-Navv Green	UV-B	6.64	4.91	
AL	"	"	UV-B	6.22		
AL	"	"	UV-A	5.53		
AL	"	"	UV-A	3.11		
AL	"	"	Oven	3.07		
AL	MIL-P-23377	LVC-AF Gray	UV-B	5.24	4.07	
AL	"	"	UV-B	4.74		
AL	"	"	UV-A	4.15		
AL	"	"	UV-A	3.21		
AL	"	"	Oven	2.99		





**Figure C-7. Albany Type II DMB Strippability  
with MIL-P-23377 Primer and Aluminum Substrate**



**Figure C-8. Albany Type II DMB Strippability  
with MIL-P-53022 Primer and Aluminum Substrate**

**Table C-4. Albany Garnet Grit DMB Process Strippability Data**

SUBSTRATE	PRIMER	TOP COAT	Age/Cure	Strip Rate, ft <sup>2</sup> /min	Avg ft <sup>2</sup> /min	Notes
AL	MIL-P-53022	MIL-C-46168	UV-B	4.27	4.88	
AL	"	"	UV-B	5.19		2% TC remained and subtracted from total area.
AL	"	"	UV-B	4.74		1% TC remained and subtracted from total area.
AL	"	"	Oven	5.33		
AL	MIL-P-23377	MIL-C-46168	UV-B	5.19	7.15	1% TC remained and subtracted from total area.
AL	"	"	UV-B	5.27		1% TC remained and subtracted from total area.
AL	"	"	UV-B	10.53		1% TC remained and subtracted from total area.
AL	"	"	Oven	7.61		
AL	MIL-P-53022	MIL-C-29475	UV-B	4.26	5.34	1% TC remained and subtracted from total area.
AL	"	"	UV-B	5.51		2% TC remained and subtracted from total area.
AL	"	"	UV-B	6.55		
AL	"	"	Oven	5.04		
AL	MIL-P-23377	MIL-C-29475	UV-B	9.28	9.89	
AL	"	"	UV-B	8.07		1% TC remained and subtracted from total area.
AL	"	"	UV-B	8.88		1% TC remained and subtracted from total area.
AL	"	"	Oven	13.32		
AL	MIL-P-53022	Low VOC CARC	UV-B	6.19	6.00	
AL	"	"	UV-B	7.40		1% TC remained and subtracted from total area.
AL	"	"	UV-B	5.55		1% TC remained and subtracted from total area.
AL	"	"	Oven	4.85		1% TC remained and subtracted from total area.
AL	MIL-P-23377	Low VOC CARC	UV-B	16.41	15.83	
AL	"	"	UV-B	19.69		
AL	"	"	UV-B	19.69		
AL	"	"	Oven	7.53		
ST	MIL-P-53022	MIL-C-46168	UV-B	4.92	6.15	
ST	"	"	UV-B	6.15		
ST	"	"	UV-B	6.56		
ST	"	"	Oven	6.95		
ST	MIL-P-53022	MIL-C-29475	UV-B	10.20	7.86	
ST	"	"	UV-B	8.82		2% TC remained and subtracted from total area.
ST	"	"	UV-B	6.56		
ST	"	"	Oven	5.86		1% TC remained and subtracted from total area.
ST	MIL-P-53022	Low VOC CARC <sup>1</sup>	UV-B	6.77	6.97	1% TC remained and subtracted from total area.
ST	"	"	UV-B	5.58		1% TC remained and subtracted from total area.
ST	"	"	UV-B	8.95		
ST	"	"	Oven	6.58		

1 - Navy color.

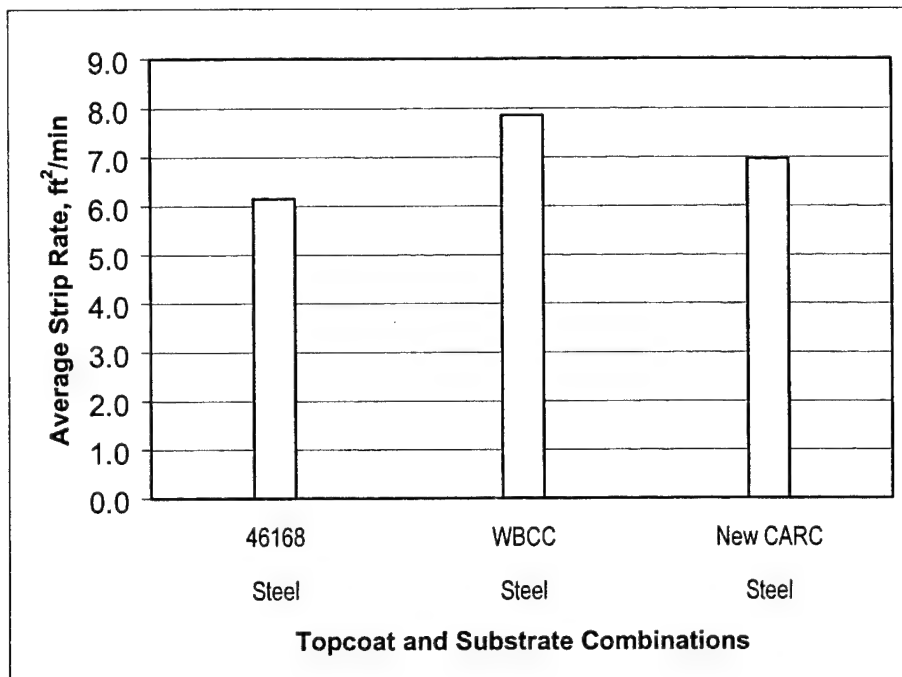


Figure C-9. Albany Garnet Grit DMB Strippability with MIL-P-53022 Primer

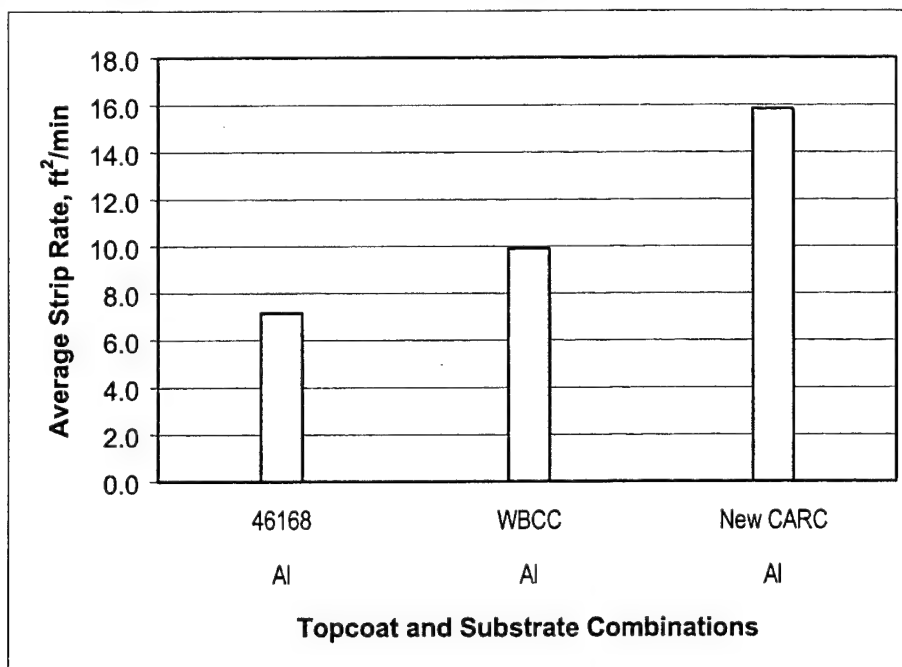
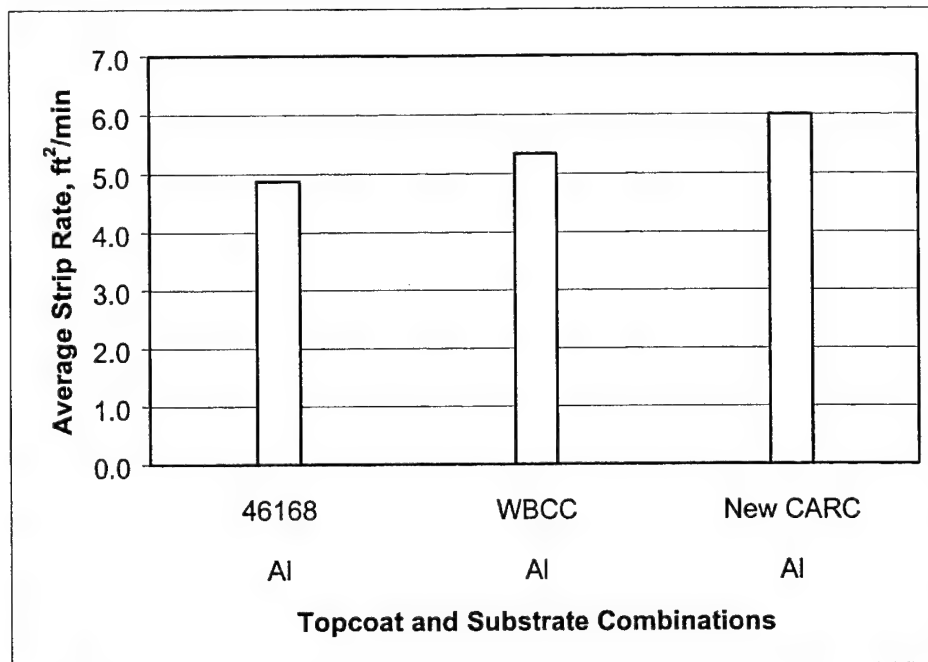


Figure C-10. Albany Garnet Grit DMB Strippability with MIL-P-23377 Primer



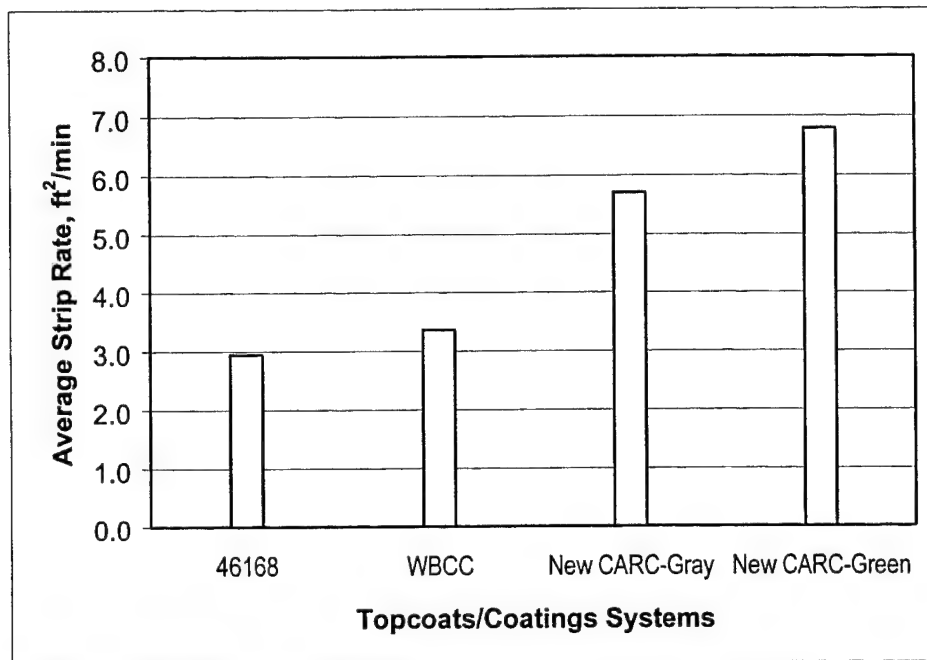
**Figure C-11. Albany Garnet Grit DMB Strippability with MIL-P-53022 Primer**

**Table C-5. Ogden-Air Logistics Center Type V Process Strippability Data**

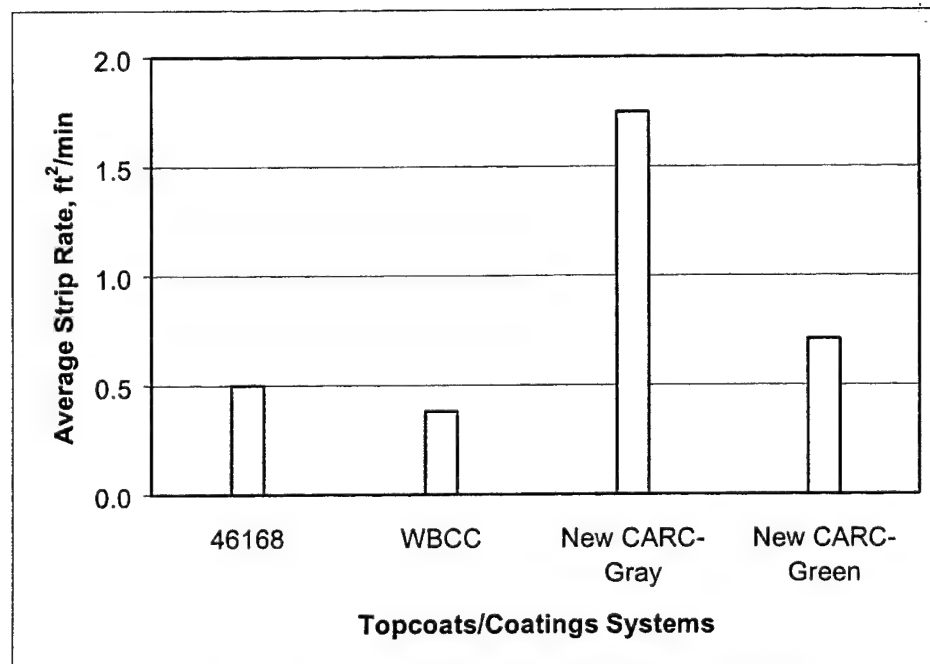
SUBSTRATE	PRIMER	TOP COAT	Age/Cure	Strip Rate, ft <sup>2</sup> /min	Set Avg, ft <sup>2</sup> /min	Notes
AL	MIL-P-23377	MIL-C-46168	UV-B	2.12	<b>2.94</b>	
AL	"	"	UV-B	2.01		
AL	"	"	UV-A	3.56		
AL	"	"	UV-A	5.08		
AL	"	"	Oven	1.95		
AL	MIL-P-23377	MIL-C-29475	UV-B	2.76	<b>3.36</b>	
AL	"	"	UV-B	3.35		
AL	"	"	UV-A	4.00		
AL	"	"	UV-A	3.30		
AL	"	"	Oven	3.41		
AL	MIL-P-23377	Low VOC CARC <sup>1</sup>	UV-B	6.82	<b>6.79</b>	
AL	"	"	UV-B	11.43		
AL	"	"	UV-A	6.15		
AL	"	"	UV-A	6.93		
AL	"	"	Oven	2.64		
AL	MIL-P-23377	Low VOC CARC <sup>2</sup>	UV-B	6.15	<b>5.71</b>	
AL	"	"	UV-B	6.88		
AL	"	"	UV-A	4.89		
AL	"	"	UV-A	6.56		
AL	"	"	Oven	4.08		
AL	MIL-P-53022	MIL-C-46168	UV-B	0.12	<b>0.50</b>	
AL	"	"	UV-B	0.23		
AL	"	"	UV-A	0.98		
AL	"	"	UV-A	1.09		
AL	"	"	Oven	0.08		
AL	MIL-P-53022	MIL-C-29475	UV-B	0.25	<b>0.38</b>	Topcoat removed in 66s
AL	"	"	UV-B	0.21		Topcoat removed in 67s
AL	"	"	UV-A	0.60		
AL	"	"	UV-A	0.75		
AL	"	"	Oven	0.10		Topcoat removed in 90s
AL	MIL-P-53022	Low VOC CARC <sup>1</sup>	UV-B	0.68	<b>0.71</b>	
AL	"	"	UV-B	0.86		Topcoat removed in 36s
AL	"	"	UV-A	0.80		
AL	"	"	UV-A	1.07		
AL	"	"	Oven	0.14		
AL	MIL-P-53022	Low VOC CARC <sup>2</sup>	UV-B		<b>1.75</b>	
AL	"	"	UV-B			
AL	"	"	UV-A	2.00		
AL	"	"	UV-A	2.60		
AL	"	"	Oven	0.64		

1 - Navy color.

2 - AF Gray



**Figure C-12. Ogden-ALC Type V DMB Strippability  
with AL Substrate and MIL-P-23377 Primer**



**Figure C-13. Ogden-ALC Type V DMB Strippability  
with AL Substrate and MIL-P-53022 Primer**

**Table C-6. Anniston Army Depot Steel Shot Process Strippability Data**

SUBSTRATE	PRIMER	TOP COAT	Age/Cure	Strip Rate, ft <sup>2</sup> /min	Set Avg, ft <sup>2</sup> /min	Notes
AL	MIL-P-53022	MIL-C-46168	UV-B	1.71	1.71	5% TC remained and subtracted from total area.
AL	"	"	UV-B	1.71		5% TC remained and subtracted from total area.
AL	"	"	UV-B	1.75		5% TC remained and subtracted from total area.
AL	"	"	Oven	1.66		2% TC remained and subtracted from total area.
AL	MIL-P-23377	MIL-C-46168	UV-B	4.37	3.74	
AL	"	"	UV-B	3.29		
AL	"	"	UV-B	3.86		
AL	"	"	Oven	3.43		
AL	MIL-P-53022	MIL-C-29475	UV-B	1.97	1.99	2% TC remained and subtracted from total area.
AL	"	"	UV-B	2.02		2% TC remained and subtracted from total area.
AL	"	"	UV-B	1.75		5% TC remained and subtracted from total area.
AL	"	"	Oven	2.22		5% TC remained and subtracted from total area.
AL	MIL-P-23377	MIL-C-29475	UV-B	3.16	2.98	
AL	"	"	UV-B	1.69		
AL	"	"	UV-B	3.73		2% TC remained and subtracted from total area.
AL	"	"	Oven	3.35		
AL	MIL-P-53022	Low VOC CARC	UV-B	2.62	2.50	2% TC remained and subtracted from total area.
AL	"	"	UV-B	2.62		2% TC remained and subtracted from total area.
AL	"	"	UV-B	2.66		2% TC remained and subtracted from total area.
AL	"	"	Oven	2.09		2% TC remained and subtracted from total area.
AL	MIL-P-23377	Low VOC CARC	UV-B	3.31	3.47	
AL	"	"	UV-B	3.75		
AL	"	"	UV-B	3.87		
AL	"	"	Oven	2.94		2% TC remained and subtracted from total area.
ST	MIL-P-53022	MIL-C-46168	UV-B	3.46	3.79	
ST	"	"	UV-B	4.12		
ST	"	"	UV-B	3.65		
ST	"	"	Oven	3.92		
ST	MIL-P-53022	MIL-C-29475	UV-B	3.73	3.90	2% TC remained and subtracted from total area.
ST	"	"	UV-B	4.59		
ST	"	"	UV-B	3.71		
ST	"	"	Oven	3.57		
ST	MIL-P-53022	Low VOC CARC <sup>1</sup>	UV-B	3.73	3.83	
ST	"	"	UV-B	4.12		
ST	"	"	UV-B	3.42		
ST	"	"	Oven	4.07		

1 - Navy Color

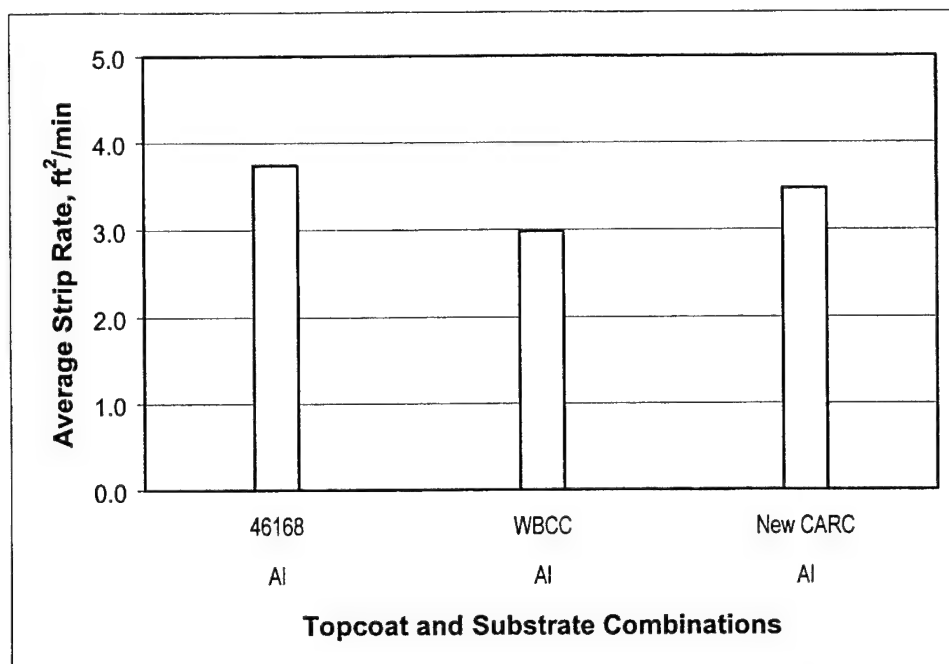


Figure C-14. Anniston Steel Shot DMB Strippability with MIL-P-23377 Primer

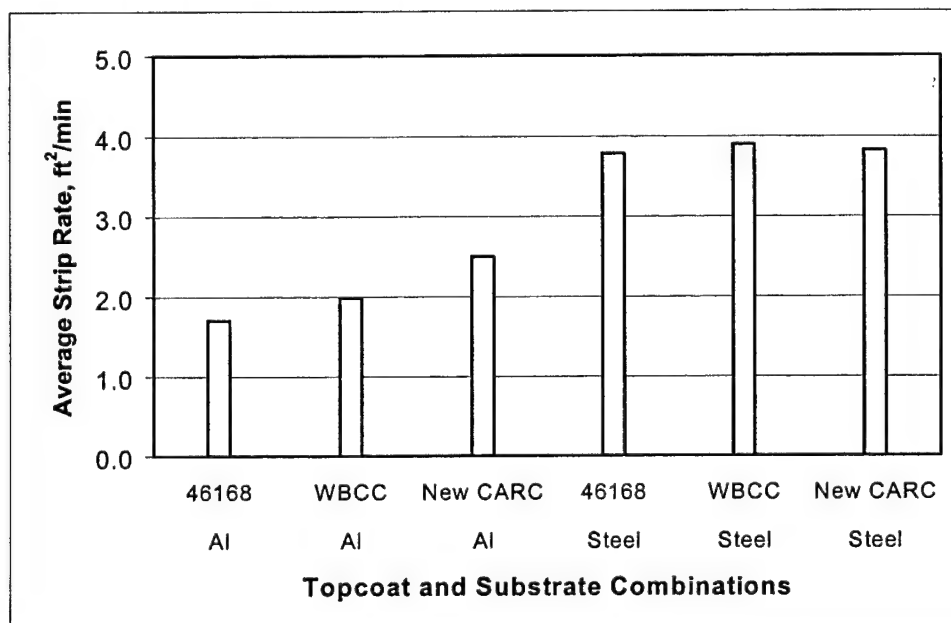


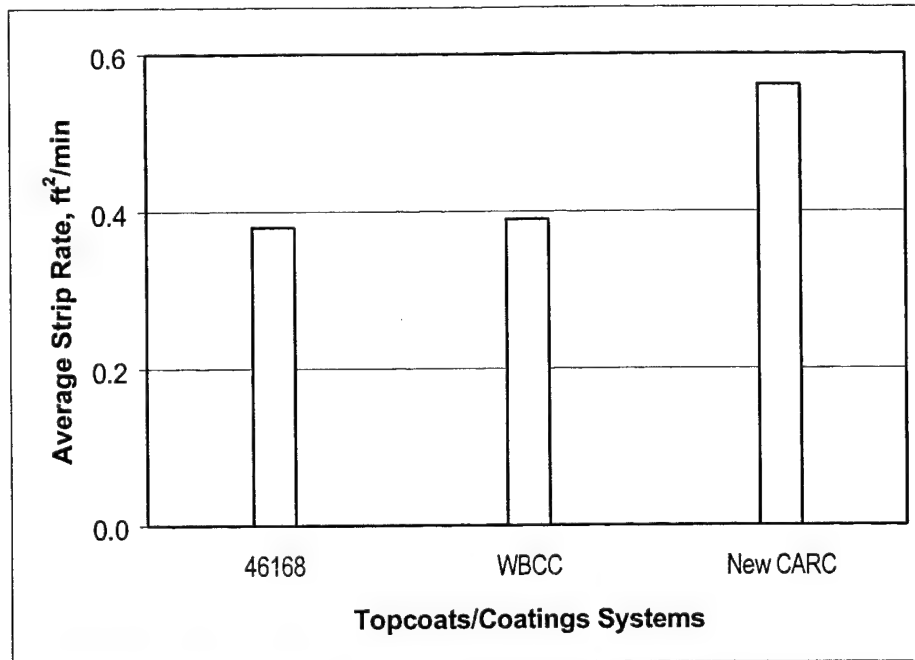
Figure C-15. Anniston Steel Shot DMB Strippability with MIL-P-53022 Primer



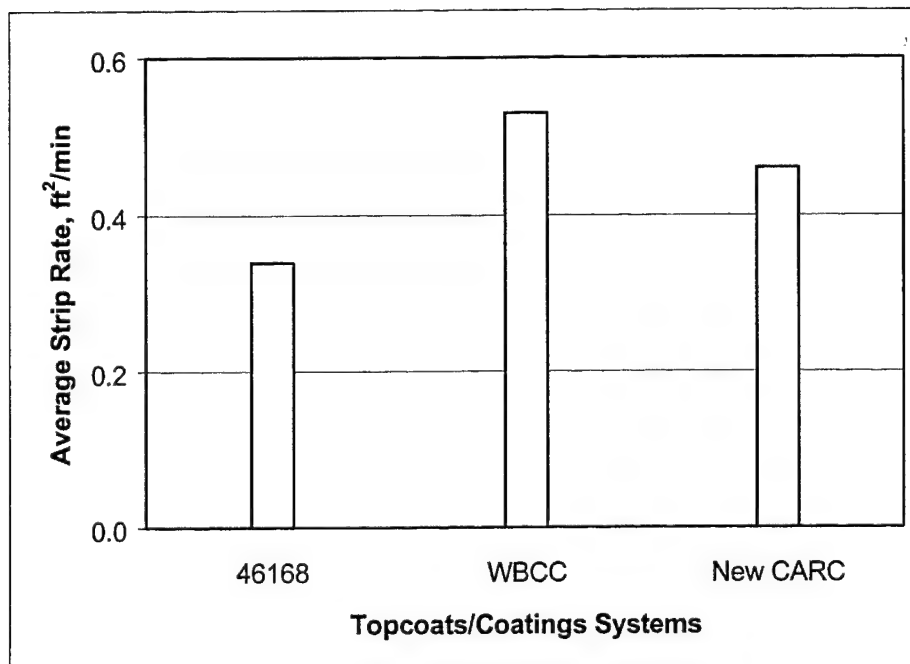
**Table C-7. Corpus Christi Army Depot Wheatstarch Media Strippability Data**

SUBSTRATE	PRIMER	TOP COAT	Age/Cure	Strip Rate, ft <sup>2</sup> /min	Set Avg, ft <sup>2</sup> /min	Notes
Fiberglass	MIL-P-53022	MIL-C-46168	Oven	0.34	0.34	
	"	"	Oven	0.34		
	"	"	Oven	0.35		
Fiberglass	MIL-P-53022	MIL-C-29475	Oven	0.55	0.53	
	"	"	Oven	0.60		
	"	"	Oven	0.44		
Fiberglass	MIL-P-53022	Low VOC CARC <sup>1</sup>	Oven	0.40	0.46	
	"	"	Oven	0.43		
	"	"	Oven	0.54		
Fiberglass	MIL-P-23377	MIL-C-46168	Oven	0.42	0.38	
	"	"	Oven	0.36		
	"	"	Oven	0.37		Stop Watch SU/ET Estimate
Fiberglass	MIL-P-23377	MIL-C-29475	Oven	0.49	0.39	
	"	"	Oven	0.40		
	"	"	Oven	0.28		
Fiberglass	MIL-P-23377	Low VOC CARC <sup>1</sup>	Oven	0.57	0.56	
	"	"	Oven	0.56		
	"	"	Oven			

1 - Navy Color



**Figure C-16. CCAD Starch WheatStarch Media Strippability with Fiberglass Substrate and MIL-P-23377 Primer**



**Figure C-17. CCAD WheatStarch Media Strippability with Fiberglass Substrate and MIL-P-53022 Primer**

# **Appendix D**

## **CHEMICAL DEPAINT STRIPPABILITY DATA**

## **General Procedures**

Samples representing each topcoat, primer, substrate combination were sheared to approximately 3" × 4" in size. Three hundred (300) milliliters of each chemical were placed in a 1000 ml beaker. Beakers were then placed into an oven, and temperature was elevated as specified by each base's identified procedure. Temperature was checked by thermocouple probe and when at temperature, sample specimens were added. Each specimen was checked every 15 minutes for strip status. When each sample specimen was completely stripped, its actual strip time was noted. If any abnormal results were noted, the respective base was called for consultation and a second test was performed as deemed necessary. Base specific procedures and results are discussed in Table D-1.

**Table D-1. Chemical Stripping Process(es) and Associated Maintenance Operation**

<b>Organization</b>	<b>Chemical ID</b>	<b>Substrate</b>	<b>Bath Temp</b>	<b>Dwell</b>	<b>Post Bath Process</b>
Anniston Army Depot	Penetone NPX	Both	Ambient	0.25 - 2 hrs	cold water rinse w/water hose, hot water bath at 60°C(140°F)
Barstow Marine Depot	70% Sodium Hydroxide 30% Sodium Gluconate	Ferrous	93°C (200°F)	1-12 hrs	warm water rinse
Red River Army Depot	Ameratec ADL-220	Ferrous	82°C (180°F)	≤ 2 hrs	hot water rinse at 82°C(180°F), apply 25% phosphoric acid, cold water rinse
Red River Army Depot	Calgon EZE-545	Non-ferrous	60°C (140°F)	0.5 hrs	hot water rinse at 82°C(180°F), mechanically abrade as necessary to remove residue
Red River Army Depot <sup>1</sup>	Turco 6088A-Thin	Non-ferrous	60°C (140°F)	0.5 hrs	hot water rinse at 82°C(180°F)
Tobyhanna Army Depot	Turco 6088A-Thin	Non-ferrous	49°C (120°F)	≤ 12 hrs	warm water rinse

1 - Primary process used for non-ferrous materials by Red River.

## Anniston Army Depot

Anniston Army Depot (ANAD) identified Penetone NPX is used for their chemical stripping efforts for both ferrous and non-ferrous materials. ANAD uses this chemical in immersion vats at ambient temperatures with an immersion time as little as 15 minutes.

Local testing of this chemical was performed per the General Procedures section and the results are noted in Table D-2.

**Table D-2. Anniston Army Depot: Penetone NPX<sup>1</sup> at Ambient Temperature**

Panel Serial #	Substrate	Primer	Topcoat	Aging Process	Expected Duration	Actual Strip Time <sup>3</sup>	Notes
189	Steel	53022	46168	Oven	15m-2h	15m	
213	Steel	53022	29475	Oven	15m-2h	15m	
230	Steel	53022	LVC <sup>2</sup> (Grey)	Oven	15m-2h	15m	
188	Steel	53022	46168	UVB	15m-2h	15m	
207	Steel	53022	29475	UVB	15m-2h	15m	
233	Steel	53022	LVC(Grey)	UVB	15m-2h	15m	
6	Aluminum	53022	46168	Oven	15m-2h	1h-45m	
53	Aluminum	53022	29475	Oven	15m-2h	1h	
86	Aluminum	53022	LVC(Grey)	Oven	15m-2h	1h-30m	
33	Aluminum	23377	46168	Oven	15m-2h	15m	
73	Aluminum	23377	29475	Oven	15m-2h	15m	
113	Aluminum	23377	LVC(Grey)	Oven	15m-2h	15m	
123	Aluminum	53022	46168	UVA	15m-2h	15m	
131	Aluminum	53022	29475	UVA	15m-2h	15m	
139	Aluminum	53022	LVC(Grey)	UVA	15m-2h	15m	
155	Aluminum	23377	46168	UVA	15m-2h	15m	
163	Aluminum	23377	29475	UVA	15m-2h	15m	
147	Aluminum	23377	LVC(Grey)	UVA	15m-2h	15m	
10	Aluminum	53022	46168	UVB	15m-2h	15m	
52	Aluminum	53022	29475	UVB	15m-2h	15m	
94	Aluminum	53022	LVC(Grey)	UVB	15m-2h	15m	
156	Aluminum	23377	46168	UVB	15m-2h	15m	
164	Aluminum	23377	29475	UVB	15m-2h	15m	
148	Aluminum	23377	LVC(Grey)	UVB	15m-2h	15m	

1. Penetone NPX is a methylene chloride based stripper.
2. LVC (SERDP Low VOC CARC)
3. All panels in this set had 100% stripping of tested area.

## Barstow Marine Depot

Barstow Marine Depot identified a mixture of Sodium Hydroxide and Sodium Gluconate in a 70%/30% solution, respectively. This process is used for their chemical stripping efforts for ferrous materials. Barstow uses this chemical in immersion vats heated to 200 °F with an immersion time of 1 hour – 12 hours.

These chemicals were procured and mixed per the Barstow ratios. Local testing of this chemical was performed per the General Procedures section and the results are noted in Table D-3.

**Table D-3. Barstow Marine Depot: Sodium Hydroxide/Gluconate<sup>1</sup> at 200 °F for 12 hours**

Panel Serial #	Substrate	Primer	Topcoat	Aging Process	Expected Duration	Actual Strip Time (Area) <sup>2</sup>	Notes
194	Steel	53022	46168	Oven	1-12h	12h (<10%)	3
217	Steel	53022	29475	Oven	1-12h	12h (<10%)	3
233	Steel	53022	LVC(Grey)	Oven	1-12h	12h (<10%)	3
196	Steel	53022	46168	Oven	1-12h	12h (<10%)	3,4
218	Steel	53022	29475	Oven	1-12h	12h (<10%)	3,4
234	Steel	53022	LVC(Grey)	Oven	1-12h	12h (<10%)	3,4
188	Steel	53022	46168	UVB	1-12h	12h (<10%)	3
207	Steel	53022	29475	UVB	1-12h	12h (<10%)	3
233	Steel	53022	LVC(Grey)	UVB	1-12h	12h (<50%)	3
195	Steel	53022	46168	UVB	1-12h	12h (<10%)	3,4
216	Steel	53022	29475	UVB	1-12h	12h (<10%)	3,4
234	Steel	53022	LVC(Grey)	UVB	1-12h	12h (<50%)	3,4

1. Ferrous materials only.
2. Stripped area of panel at maximum expected duration shown in parentheses, if not 100%.
3. Barstow reports results not abnormal. Chemical normally used for rust removal. Parts are removed when rust removal has been accomplished or 24 hours whichever comes first.
4. Second set was performed to verify data.

## Red River Army Depot

This chemical is used at Red River Army Depot (RRAD) for CARC removal on ferrous materials. RRAD uses this chemical in immersion vats at a temperature of 180 °F with immersion times as much as 2 hours.

Local testing of this chemical was performed per the General Procedures section and the results are noted in Table D-4.

**Table D-4. Red River Army Depot: Ameritech ADL-220<sup>1</sup> at 180 °F for 2 hours**

Panel Serial #	Substrate	Primer	Topcoat	Aging Process	Expected Duration	Actual Strip Time (Area) <sup>2</sup>	Notes
194	Steel	53022	46168	Oven	≤ 2 hours	2h (0%)	3
217	Steel	53022	29475	Oven	≤ 2 hours	2h (0%)	3
233	Steel	53022	LVC(Grey)	Oven	≤ 2 hours	2h (0%)	3
195	Steel	53022	46168	Oven	≤ 2 hours	2h (0%)	3,4
218	Steel	53022	29475	Oven	≤ 2 hours	2h (0%)	3,4
234	Steel	53022	LVC(Grey)	Oven	≤ 2 hours	2h (0%)	3,4
188	Steel	53022	46168	UVB	≤ 2 hours	2h (0%)	3
207	Steel	53022	29475	UVB	≤ 2 hours	2h (0%)	3
233	Steel	53022	LVC(Grey)	UVB	≤ 2 hours	2h (0%)	3
195	Steel	53022	46168	UVB	≤ 2 hours	2h (0%)	3,4
216	Steel	53022	29475	UVB	≤ 2 hours	2h (0%)	3,4
234	Steel	53022	LVC(Grey)	UVB	≤ 2 hours	2h (0%)	3,4

1. Ferrous materials only.
2. Stripped area of panel at maximum expected duration shown in parentheses, if not 100%.
3. Red River reports normal results for chemical and are researching a replacement.
4. Second set was performed to verify data.

This chemical is used at Red River Army Depot (RRAD) for CARC removal on non-ferrous materials. RRAD uses this chemical in immersion vats at a temperature of 140 °F with an immersion time as little as 30 minutes.

Local testing of this chemical was performed per the General Procedures section and the results are noted in Table D-5.

**Table D-5. Red River Army Depot: Calgon EZE-545<sup>1</sup> at 140 °F for 30 minutes minimum**

Panel Serial #	Substrate	Primer	Topcoat	Aging Process	Expected Duration	Actual Strip Time <sup>2</sup>	Notes
11	Aluminum	53022	46168	Oven	30m min	2h 45m	
50	Aluminum	53022	29475	Oven	30m min	2h 45m	
91	Aluminum	53022	LVC(Green)	Oven	30m min	4h 15m	
31	Aluminum	23377	46168	Oven	30m min	45m	
75	Aluminum	23377	29475	Oven	30m min	30m	
105	Aluminum	23377	LVC(Green)	Oven	30m min	1h	
124	Aluminum	53022	46168	UVB	30m min	1h 15m	
132	Aluminum	53022	29475	UVB	30m min	2h 30m	
140	Aluminum	53022	LVC(Green)	UVB	30m min	3h 15m	
156	Aluminum	23377	46168	UVB	30m min	45m	
164	Aluminum	23377	29475	UVB	30m min	30m	
172	Aluminum	23377	LVC(Green)	UVB	30m min	30m	
123	Aluminum	53022	46168	UVA	30m min	1h 45m	
131	Aluminum	53022	29475	UVA	30m min	1h 45m	
139	Aluminum	53022	LVC(Green)	UVA	30m min	2h 45m	
155	Aluminum	23377	46168	UVA	30m min	30m	
163	Aluminum	23377	29475	UVA	30m min	30m	
171	Aluminum	23377	LVC(Green)	UVA	30m min	30m	

1. Non-Ferrous material only.

2. All panels in this set had 100% stripping of tested area.



This is the primary chemical used at Red River Army Depot (RRAD) for CARC removal on non-ferrous materials. RRAD uses this chemical in immersion vats at a temperature of 140 °F with an immersion time as little as 30 minutes.

Local testing of this chemical was performed per the General Procedures section and the results are noted in Table D-6.

**Table D-6. Red River Army Depot: Turco 6088A-Thin<sup>1</sup> at 140 °F for 30 minutes minimum**

Panel Serial #	Substrate	Primer	Topcoat	Aging Process	Expected Duration	Actual Strip Time (Area) <sup>2</sup>	Notes
11	Aluminum	53022	46168	Oven	30m min	12h (25%)	
50	Aluminum	53022	29475	Oven	30m min	1h 15m	
91	Aluminum	53022	LVC(Green)	Oven	30m min	3h	
31	Aluminum	23377	46168	Oven	30m min	15m	
75	Aluminum	23377	29475	Oven	30m min	15m	
105	Aluminum	23377	LVC(Green)	Oven	30m min	15m	
124	Aluminum	53022	46168	UVB	30m min	15m	
132	Aluminum	53022	29475	UVB	30m min	45m	
140	Aluminum	53022	LVC(Green)	UVB	30m min	45m	
156	Aluminum	23377	46168	UVB	30m min	30m	
164	Aluminum	23377	29475	UVB	30m min	15m	
172	Aluminum	23377	LVC(Green)	UVB	30m min	30m	
18	Aluminum	53022	46168	UVA	30m min	1h	
131	Aluminum	53022	29475	UVA	30m min	1h	
25	Aluminum	53022	LVC(Green)	UVA	30m min	30m	
155	Aluminum	23377	46168	UVA	30m min	15m	
163	Aluminum	23377	29475	UVA	30m min	15m	
171	Aluminum	23377	LVC(Green)	UVA	30m min	15m	

1. Non-Ferrous material only.

2. Stripped area of panel at maximum expected duration shown in parentheses, if not 100%.

### Tobyhanna Army Depot

This chemical is used at Tobyhanna Army Depot for CARC removal on non-ferrous materials. Tobyhanna uses this chemical in immersion vats at a temperature of 120 °F with an immersion times of 1-12 hours.

Local testing of this chemical was performed per the General Procedures section and the results are noted in Table D-7.

**Table D-7. Tobyhanna Army Depot: Turco 6088A-Thin<sup>1</sup> at 120 °F for 2-4 hours**

Panel Serial #	Substrate	Primer	Topcoat	Aging Process	Expected Duration	Actual Strip Time (Area) <sup>2</sup>	Notes
12	Aluminum	53022	46168	Oven	1-12h	12h (25%)	
49	Aluminum	53022	29475	Oven	1-12h	2h	
90	Aluminum	53022	LVC(Green)	Oven	1-12h	4h	
29	Aluminum	23377	46168	Oven	1-12h	45m	
75	Aluminum	23377	29475	Oven	1-12h	30m	
103	Aluminum	23377	LVC(Green)	Oven	1-12h	30m	
10	Aluminum	53022	46168	UVB	1-12h	12h (25%)	
132	Aluminum	53022	29475	UVB	1-12h	1h 15m	
94	Aluminum	53022	LVC(Green)	UVB	1-12h	1h 15m	
156	Aluminum	23377	46168	UVB	1-12h	30m	
164	Aluminum	23377	29475	UVB	1-12h	15m	
172	Aluminum	23377	LVC(Green)	UVB	1-12h	15m	
21	Aluminum	53022	46168	UVA	1-12h	45m	
18	Aluminum	53022	29475	UVA	1-12h	1h	
25	Aluminum	53022	LVC(Green)	UVA	1-12h	45m	
155	Aluminum	23377	46168	UVA	1-12h	30m	
163	Aluminum	23377	29475	UVA	1-12h	15m	
171	Aluminum	23377	LVC(Green)	UVA	1-12h	30m	

1. Non-Ferrous material only.

2. Stripped area of panel at maximum expected duration shown in parentheses, if not 100%.

# **Appendix E**

## **CARC STRIPPABILITY DATA for APPLIED LIGHT ENERGY PROCESSES**

**Table E-1. Flashjet Strippability Data .**

SUBSTRATE	PRIMER	TOP COAT	Age/Cure	Strip Rate, ft <sup>2</sup> /min	Avg ft <sup>2</sup> /min	Notes
FG	MIL-P-53022	MIL-C-46168	Oven	2.44	2.18	Significant Topcoat
FG	"	"	Oven	2.06		"
FG	"	"	Oven	2.06		"
FG	"	"	Oven	2.16		"
FG	MIL-P-23377	MIL-C-46168	Oven	3.09	3.00	Stripped to
FG	"	"	Oven	3.09		"
FG	"	"	Oven	3.00		"
FG	"	"	Oven	2.81		"
FG	MIL-P-53022	Low VOC <sup>1</sup>	Oven	4.08	3.94	Significant Bare
FG	"	"	Oven	4.05		Uniform Footprint, 50%
FG	"	"	Oven	3.80		Significant Bare
FG	"	"	Oven	3.84		Uniform Footprint 30% Bare
FG	MIL-P-23377	MIL-C-29475	Oven	4.03	4.10	Some Primer
FG	"	"	Oven	4.13		"
FG	"	"	Oven	4.15		"
FG	"	"	Oven	4.10		"
FG	MIL-P-53022	MIL-C-29475	Oven	3.05	3.18	Small Areas of Bare
FG	"	"	Oven	3.38		"
FG	"	"	Oven	3.09		"
FG	"	"	Oven	3.19		"
FG	MIL-P-23377	Low VOC <sup>1</sup>	Oven	4.24	4.13	Some Primer
FG	"	"	Oven	4.10		"
FG	"	"	Oven	4.10		"
FG	"	"	Oven	4.08		"

1 - Navy Color

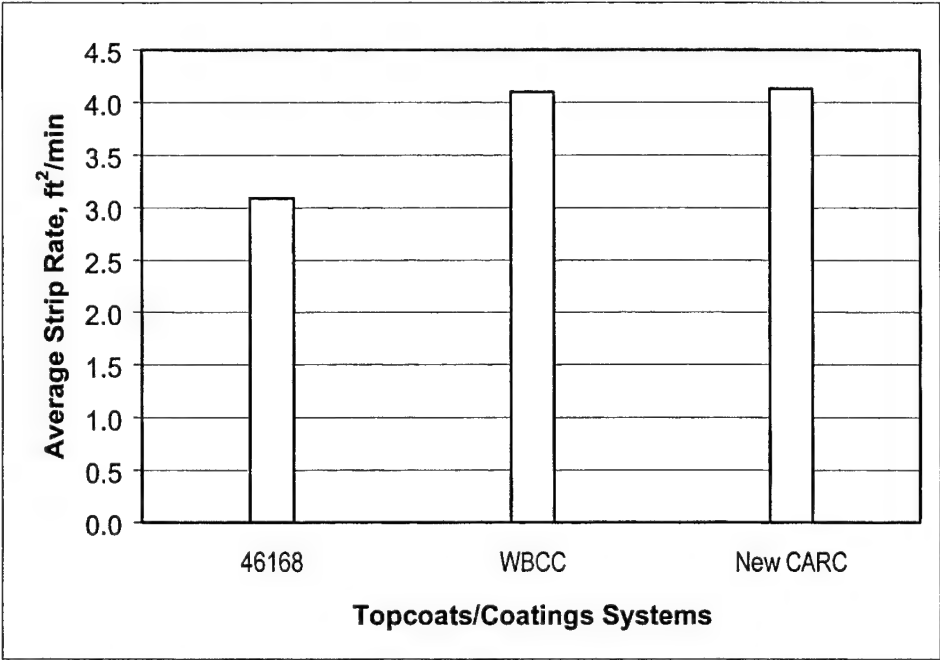


Figure E-1. FlashJet™ Strippability with Fiberglass Substrate and MIL-P-23377 Primer

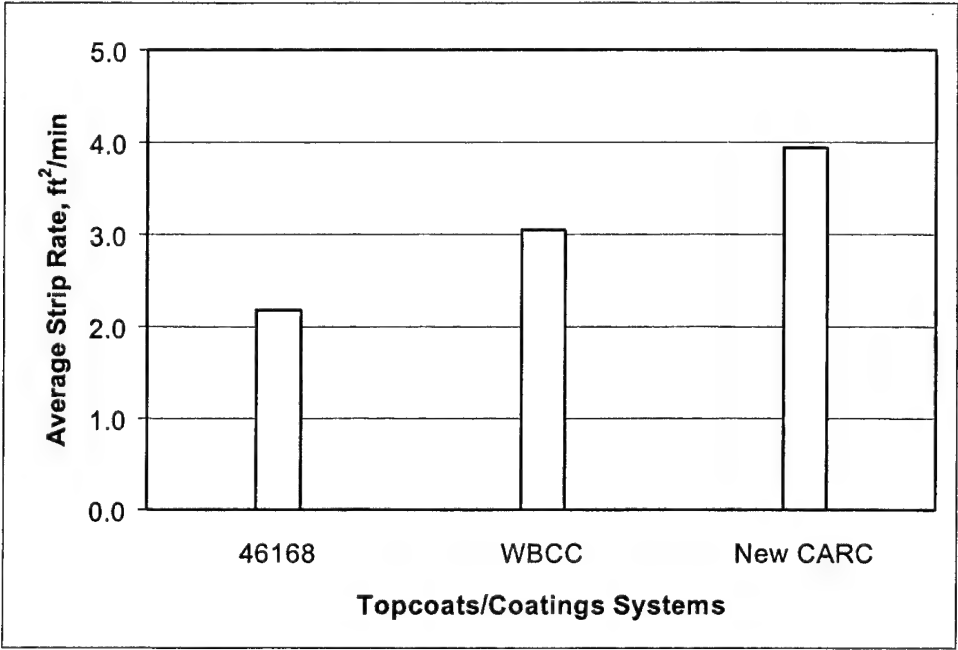
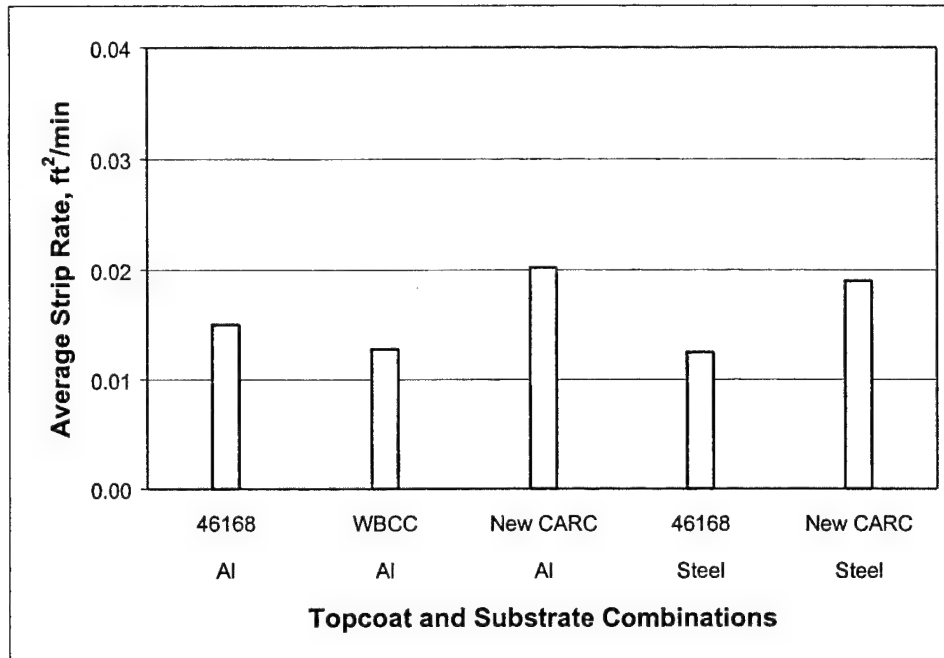


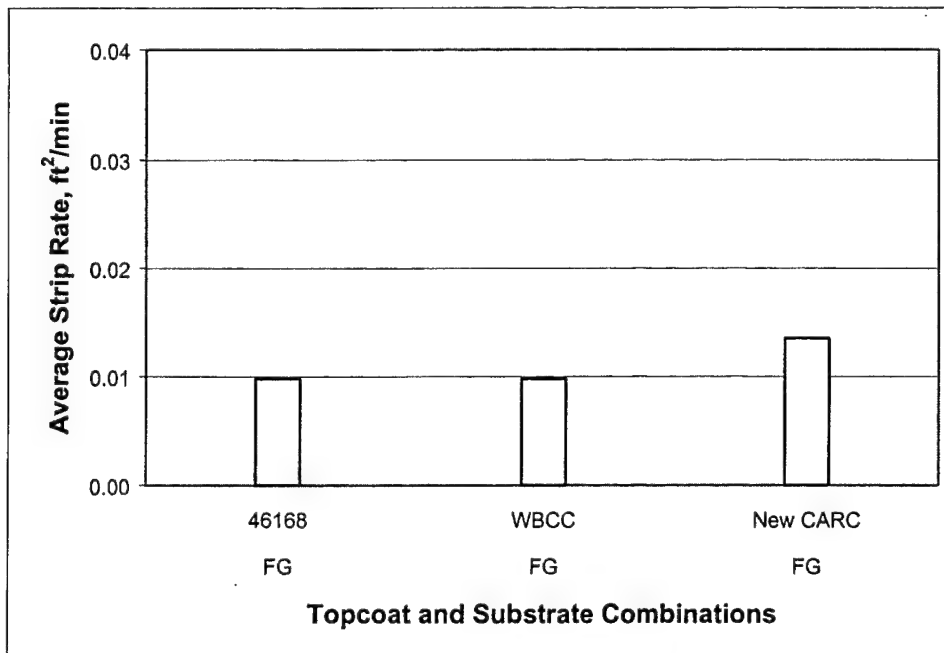
Figure E-2. FlashJet™ Strippability with Fiberglass Substrate and MIL-P-53022 Primer

**Table E-2. GLC Pulsed Nd:YAG Laser Strippability Data**

SUBSTRATE	PRIMER	Age/Cure	TOPCOAT	Avg Strip Rate, ft <sup>2</sup> /min
Al	MIL-P-53022	Oven	46168	0.0150
Al	"	Oven	WBCC	0.0128
Al	"	Oven	Low VOC CARC	0.0202
Steel	MIL-P-53022	Oven	46168	0.0125
Steel	"	Oven	Low VOC CARC	0.0190
Al	MIL-P-23377	Oven	46168	0.0157
Al	"	Oven	WBCC	0.0255
Al	"	Oven	Low VOC CARC	0.0293
FG	MIL-P-53022	Oven	46168	0.0098
FG	"	Oven	WBCC	0.0098
FG	"	Oven	Low VOC CARC	0.0135
FG	MIL-P-23377	Oven	46168	0.0110
FG	"	Oven	WBCC	0.0098
FG	"	Oven	Low VOC CARC	0.0122



**Figure E-3. GLC Pulsed Nd:YAG Laser Strippability with MIL-P-53022 Primer**



**Figure E-4. GLC Pulsed Nd:YAG Laser Strippability with MIL-P-53022 Primer**

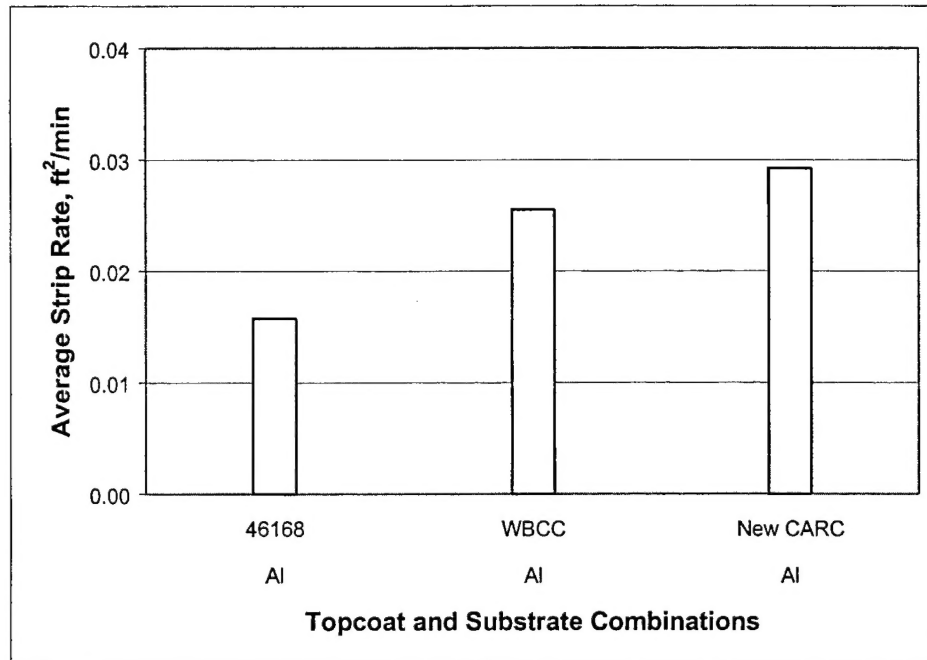


Figure E-5. GLC Pulsed Nd:YAG Laser Strippability with MIL-P-2337 Primer

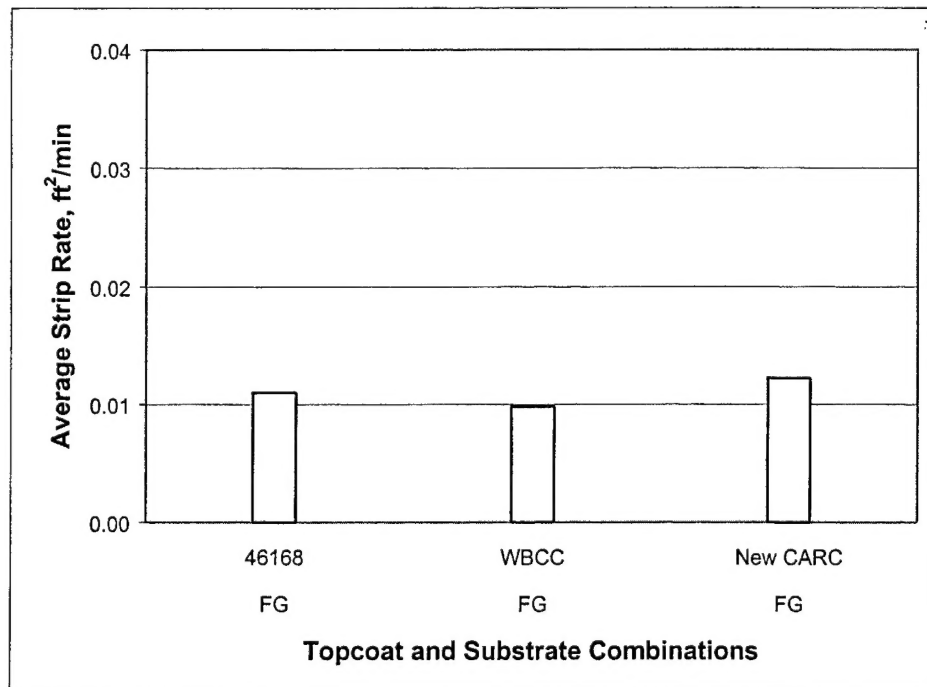


Figure E-6. GLC Pulsed Nd:YAG Laser Strippability with MIL-P-23377 Primer



**Table E-3. CWA Pulsed Nd:YAG Laser Strippability Data**

SUBSTRATE	PRIMER	Age/Cure	TOPCOAT	Avg Strip Rate, ft <sup>2</sup> /min
Al	MIL-P-53022	Oven	46168	0.0060
Al	"	Oven	WBCC	0.0024
Al	"	Oven	Low VOC CARC	0.0093
Steel	MIL-P-53022	Oven	46168	0.0049
Steel	"	Oven	Low VOC CARC	0.0059
Al	MIL-P-23377	Oven	46168	0.0018
Al	"	Oven	WBCC	0.0042
Al	"	Oven	Low VOC CARC	0.0351
FG	MIL-P-53022	Oven	46168	0.0046
FG	"	Oven	Low VOC CARC	0.0042
FG	MIL-P-23377	Oven	46168	0.0063
FG	"	Oven	WBCC	0.0074

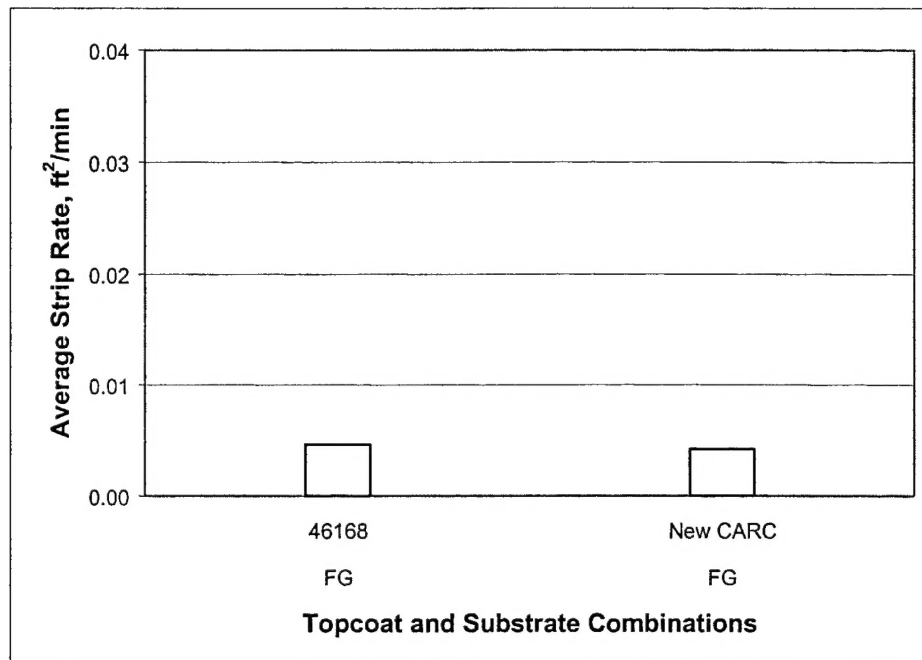


Figure E-7. CWA Pulsed Nd:YAG Laser Strippability with MIL-P-53022 Primer

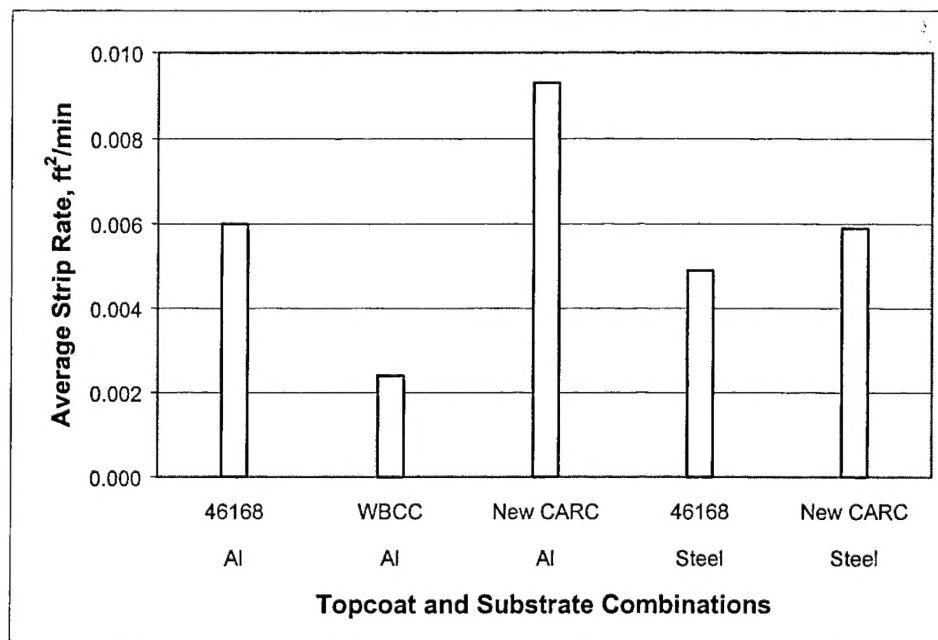


Figure E-8. CWA Pulsed Nd:YAG Laser Strippability with MIL-P-53022 Primer

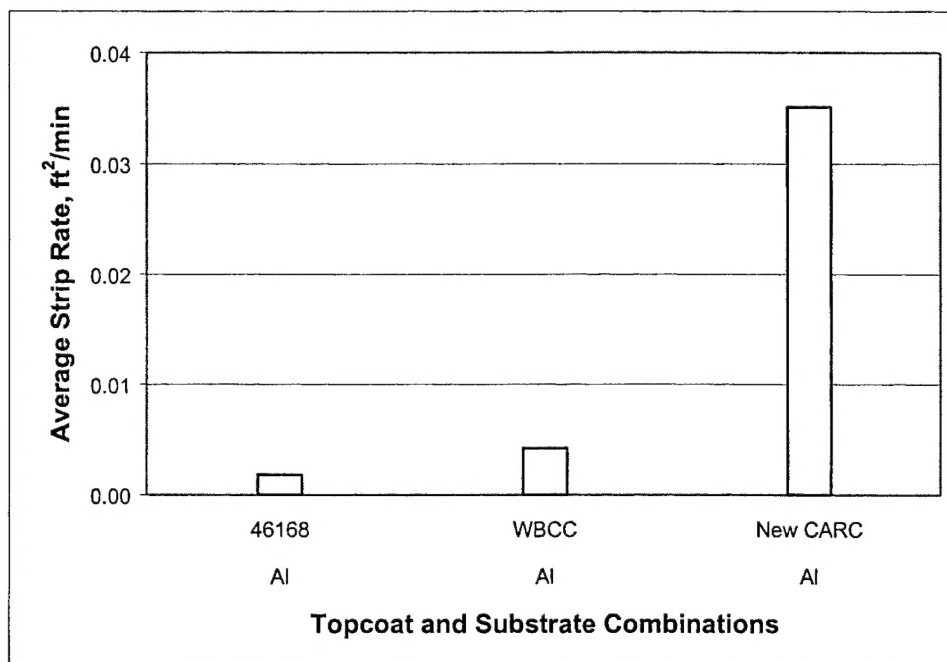


Figure E-9. CWA Pulsed Nd:YAG Laser Strippability with MIL-P-23377 Primer

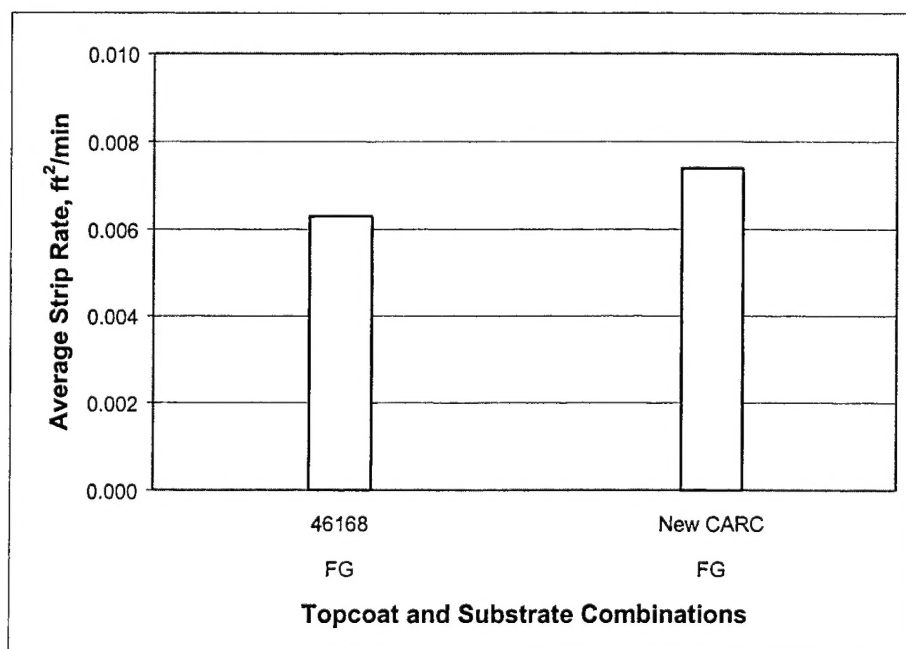


Figure E-10. CWA Pulsed Nd:YAG Laser Strippability with MIL-P-23377 Primer